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ABSTRACT

Ways to develop and manage partnerships between colleges and industry are discussed. The broad educational, economic, social, and political contexts supporting such partnerships are reviewed, along with the important supporting roles of government and third parties. The dynamics of different partnership arrangements are examined, including philanthropy, procurements, linkages, exchanges, cooperatives, and joint ventures. Influences on the partnership are considered, including the diverse nature of the corporate world, and the transition to a global marketplace. Consideration is also given to high technology in a social context, education in a technological world, and the historical context for school business cooperation. The following six needs facing higher education are discussed: supporting faculty and graduate students, financing and utilizing basic research, upgrading facilities and equipment, maintaining the health of core programs, developing new patterns of education, and adapting organizational structures. The needs and interests of industry include human resource needs, and research and innovation. The management environment for a partnership and the negotiating and management of a contract are also discussed. A bibliography is appended. (SW)

Managing the Partnership Between Higher Education and Industry

Jana B. Matthews and

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1984

National Center for Higher Education Management Systems
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Foreword

"EDUCATION," Robert Frost once remarked, "is hanging around until you've caught on." Rapid changes in science and technology, however, are teaching higher education and industry that osmosis is no longer an efficient way to seek wisdom, much less wealth. In an information society, education is a strategic resource for business and industry, and knowledge the essential product. Thus interdependent, colleges and universities are entering into partnerships with corporations that will enable both to shape and secure their futures.

This book combines a strategic assessment of such partnerships with practical management advice. In forging alliances, higher education and industry must recognize that their difficulties are not limited to the financial crisis on our college campuses or the dulling of our competitive edge in the world marketplace. Rather, their problems proceed from an unfortunate and artificial isolation, alien to the fundamental nature of our educational and economic systems.

Higher education and industry have long been tacit partners. Current pressures exerted by the technological revolution suggest that it is time for this relationship to become explicit and directed toward mutual concerns. Colleges understandably demur at possible encroachments on academic freedom, and corporations have good reason to hesitate at the prospect of losing some proprietary information. However, appropriate safeguards are being found that permit them to undertake creative initiatives addressing their mutual needs and interests.

Our commitment at NCHEMS to improved management in higher education enables us to recognize the importance of these partnerships and to contribute to their effectiveness. We have helped many colleges and universities foster close, mutually beneficial ties with the business community. Our 1983 National Assembly elicited creative ideas on this topic from leaders in education, industry, and government. Usefully enlarging upon these experiences, this volume offers a cogent rationale for partnerships, and specific suggestions to improve the broad alliances upon which we all depend.

—Ben Lawrence
President
National Center for Higher
Education Management Systems

Preface

THE 1983 NCHEMS National Assembly—HIGHER EDUCATION AND INDUSTRY: MANAGING THE PARTNERSHIP—was more than a conference on partnerships between higher education and industry. The Assembly was itself a partnership, the result of contributions made by many interested parties who had worked together on the program. It exemplified those first steps so necessary in forming a partnership: a belief that partnerships are essential, an open dialogue about what each party needs, and a vision of where the partnership should go and what it should accomplish.

This book is neither a report on the Assembly nor a conference proceeding. Rather than publishing selected speeches delivered in Denver, Colorado, in February 1983, we have focused on the issues raised and the ideas shared. We have also drawn upon others who were not Assembly speakers but whose comments and viewpoints have helped expand those discussions. This volume, then, treats the Assembly not as its sole point of reference but as a valuable point of departure. Its goal, like that of the Assembly, is to foster better understanding of partnerships and contribute to their effective management.

The Assembly benefited greatly from the efforts of several partners. NCHEMS asked 11 people to advise us on the shape of the program, the issues to be addressed, and the speakers most capable of thoughtful contributions. Those associated with higher-education institutions (Richard Van Horn, George Baughman, and Roland Rautenstraus) were very familiar with NCHEMS purpose: to help higher-education institutions manage their present and shape their future. John Wirt (NIE) was also familiar with NCHEMS, because the National Institute of Education has, over the years, been a major funder of NCHEMS work. Those representing industry (Louis Branscomb, Edward E. David, Juan Rodriguez, and Roy Yamahiro) were also most generous with their advice and counsel. Advisors from professional and industrial associations (Pat Hill Hubbard and Rogers Finch) and from governmental agencies (Rhett Speer) provided valuable insights on how third parties, including NCHEMS, can foster and support partnership arrangements. These people never met together as a group, but each played a crucial role in helping us shape the conceptual and organizational framework of the conference.

The Assembly was a time of vigorous and lively discussion. This was possible because it attracted a broad cross section of possible partners: representatives from business and industry, from two-year, four-year, and research institutions, and from state and federal government were all in attendance. It is unfortunate that the many informal discussions were not captured and could not be included in this book. However, the 30 speakers who made formal presentations at the Assembly provided a depth and scope of experience that enriched all those in attendance. Their many lucid insights and observations have benefited this book immeasurably. The appendix lists these speakers and their affiliations. Because the remarks of the speakers were gleaned from unedited transcriptions not available to the public, readers can assume that unreferenced citations in the text were made by speakers at the Assembly.

This volume reflects the broad consensus among Assembly participants that partnerships between higher education and industry are not a necessary evil but a new opportunity. Like each of the Assembly speakers, we have sought to convey not only a sense of what is possible, but the tangible and exciting results of actual partnerships already underway.

This book would not have been possible without valuable contributions from many quarters. We wish to thank the following people in particular.

John Wirt, Senior Program Officer at the National Institute of Education (NIE), served as 1 of 11 advisors to NCHEMS in planning the National Assembly program. His support continued after the Assembly as well. NIE provided a substantial grant that has enabled us to write this book.

Mr. Juan Rodriguez, Vice-President for Research and Technology at Storage Technology Corporation, and Dr. Roy Yamartho, Vice-President for Organization Development and Training at Federal Express, also afforded us excellent counsel as well as financial support for this publication.

Mr. Monte Throdahl, Senior Vice-President of Monsanto Company, and Mr. Roy Cavert, Executive Vice-President of Westinghouse Electric Corporation, were major speakers at the Assembly and were also kind enough to furnish financial support for this book.

Roland Rautenstraus, former President of the University of Colorado and Professor of Engineering, provided invaluable assistance in shaping the program and helped us secure exactly the right speakers for certain topics.

Jack Bartram, Jill Goldwater, Dennis Jones, Ted Mulford, and Roland Rautenstraus took time away from their busy schedules to offer valuable comments on the manuscript.

Clara Roberts, Director of Publications Services at NCHEMS, provided the professional and highly efficient expertise that has brought these pages between two covers. Linda Miller Kemnitzer, the National Assembly Coordinator, served as archivist for many of the materials included in this volume. Linda Croom Mullins furnished word processing as tireless as it was accurate. Mary Hey provided excellent editorial assistance.

If this volume fails to reflect these many valuable contributions, the responsibility lies solely with the authors.

"As we complete our transition to an information society, it is more important than ever that we understand why higher education and industry must depart from their past isolation, recognize new forms of interdependence, and search jointly for innovative solutions in the future. To do so, we must look beyond the horizon of the ordinary and the habitual."

Introduction

> THE URGE TO FORM partnerships, to link up in collaborative arrangements, is perhaps the oldest, strongest, and most fundamental force in nature. There are no solitary, free-living creatures: every form of life is dependent on other forms. The great successes in evolution, the mutants who have, so to speak, made it, have done so by fitting in with, and sustaining, the rest of life. Up to now we might be counted among the brilliant successes, but flashy and perhaps unstable. We should go warily into the future, looking for ways to be more useful, listening more carefully for the signals, watching our step, and having an eye out for partners.
>
> Lewis Thomas [1980a, p. 21]

The urge to form partnerships extends beyond single forms of life to include communities of individuals and institutions. Recognizing not only the urge but the need to form partnerships, both higher education and industry are keeping "an eye out for partners." Symbiosis can be counted among the many forms of partnership in nature. It is an intimate association between two different organisms in which each derives benefit from, and in some cases guarantees, the other's continued existence. In exploring alliances with one another, higher education and industry have likewise recognized that their survival increasingly depends on mutual assistance. Their further evolution may well depend on their fitting in with and sustaining the institutional and economic life forms around them.

Events of the last decade have shaken the confidence of the educational and industrial communities, both of which are recognizing that isolation from the other has contributed to their present predicament. In turn, each perceives increased collaboration as a way of improving the health of higher education and the competitive position of American business. Industrial cooperation is indeed an alluring prospect for an expanding roster of educational institutions, many of which are beset by dwindling enrollments, unremitting financial pressures, faculty shortages in science and engineering, and inadequate research facilities. Declining productivity, lagging innovation, and the loss of its once-vaunted competitive advantage to foreign countries are prompting American industry to recognize in higher education a strategic source for research, innovation, and trained workers.

Although immediate needs may have induced them to enter into a dialogue, higher education and industry are discovering that they can derive substantial long-term benefits from an alliance. Our nation has traditionally depended on well-educated citizens, strong programs in basic scientific research, and a commitment to utilize new technologies as factors determining our economic growth and social well being. Our transition from an industrial to a knowledge-intensive society only increases the strategic importance of these educational resources. Higher education and industry are, as a consequence, becoming increasingly aware of their underlying interdependence.

The prospect of closer ties between corporate America and the college campus has generated substantial interest. New arrangements are carefully scrutinized, articles written, studies commissioned, and conferences convened. All are aware that high stakes are involved but that the benefits derived could be substantial.

Although a climate of optimism prevails, growing collaboration between higher education and industry has raised important questions about its long-term effect and, some would say, its propriety. The primary functions of a university and a corporation are indeed different. Although the development of new ideas and their practical application can frequently be complementary, Yale University President A. Bartlett Giamatti cautions that this "simply throws into relief the basic difference between universities and industries: the academic imperative to seek knowledge objectively and to share it openly and freely; and the industrial imperative to garner a profit, which creates the incentive to treat knowledge as private property" (1982, p. 1,279).

Unfortunately, rhetoric on the subject often obscures these issues. Fearful of what they perceive as industrial encroachment on the university campus, some educators staunchly defend a purist interpretation of academic freedom, not understanding that the dialectic between intellectual inquiry and public need is a quintessential feature of modern educational institutions. At the other extreme are those who promote rhapsodic Star Trek visions of technological progress derived from highly intimate ties between corporation and campus. These proponents of collaboration tend to overlook legitimate reservations, especially from the educational community.

When we untangle the rhetoric surrounding industry-university cooperation, we find that, while many concerns are warranted, the problems are certainly not insurmountable. As college campuses experience a shift from corporate contribution to corporate investment, many educators are wary of its impact on institutional autonomy. Their fears stem less from specific agreements on intellectual property rights contained in recent accords than from their possible cumulative, long-term effect. Some institutions worry that their financial crisis may tempt them to compromise themselves in their headlong rush to tap a newly discovered financial resource. Others, however, may be unreasonably circumspect in an attempt to prevent such a response. Concerns also haunt the industrial community. Collaboration may lessen a company's proprietary control of research information, thereby jeopardizing a return on its investment. Both parties are quickly learning that partnerships require a delicate balance. Their fears remind us of the equilibrium tenuously maintained in the biological world; if one of the symbionts is unduly favored, it may become a parasite or even outgrow the other and eventually become a predator.

A growing majority of educators and business executives are of the opinion that these risks are manageable. They argue convincingly that the benefits likely to accrue from partnerships between higher education and industry far outweigh the potential hazards. And these benefits, they add, cannot be derived unless both communities take the initiative to form alliances. The hidden costs of their long-standing adversarial relationship have only recently become apparent. Although a good deal of history will have to be lived down, and substantial misperceptions corrected, both parties are once again on speaking terms. This gives us reason to hope that the two cultures can be bridged. Like different fingers on the same hand, higher education and industry are becoming aware of their interdependence. Although an index finger and an opposed thumb can justify certain special functions, their ultimate usefulness consists in serving a larger purpose. Likewise, as business executives and educators look beyond their immediate environment, they are discovering the larger needs and interests that connect them.

Industry's participation in higher education should not be looked upon solely as largesse or as an entirely self-serving, profit-minded investment. Likewise, a college or university's cooperation with the business community need not be considered tantamount to a Faustian pact endangering its institutional soul. Rather, their partnership can be consistent with their different missions and help guarantee their health, if not survival. Unfortunately, protectionist attitudes often hinder new forms of collaboration; what one party calls integrity the other calls self-interest. Although both higher education and industry should preserve their inner logic, University of Rochester President Robert L. Sproull encourages us to "indulge in protectionism of a higher sort: we should protect our willingness and ability to take risks, to experiment, to undertake new directions, and to help [illegible] generation prepare themselves for lives of service" (1983, p. [illegible]).

Recent progress in fostering partnerships is perhaps most apparent in that we now rarely ask whether we ought to form partnerships; we wish to know how we can better develop and manage them. Where partnerships have not yet become a reality, they are often perceived as a real need. We should also be alert, however, to the danger of multiplying these alliances in careless fashion. The needs and interests of both parties must be assessed, and the vehicle for interaction appropriate to their circumstances. Like Robert Rosenzweig and Barbara Turlington, we feel that "the best time to be thoughtful about those links is at the start when they are still malleable so that what is learned from early experience can be used to improve later practice and so that unreasonable expectations do not lead to disappointment and disenchantment" (1982, p. 43). Although it augurs well as a first step, the mere joining of hands will not prove sufficient. Higher education and industry will need to marshall other and more important strengths, foremost being their creativity, foresight, and capacity for mutual understanding.

This book addresses how we can develop and effectively manage these partnerhips, whether in research or in human-resource development. We need to understand why these alliances are both necessary and mutually beneficial, what interests and needs should guide our actions, and what principles should be used to better manage and direct our efforts. Most obstacles can be overcome if both parties are willing to work together in a spirit of cooperation and mutual understanding. The structure of this book takes shape from this basic premise.

Because management issues require a strategic perspective, we sketch out in chapter 1 the broad educational, economic, social, and political contexts that render partnerships so important and necessary.

In chapter 2 we reveal, in some detail, the interests and needs of higher education and industry, and comment on the important supporting role that government and third parties can play. We do not deal extensively with national policy or the role that the federal government might assume. Of more immediate consequence are actual working partnerships and the lessons they have to teach us about fostering and managing these alliances.

In chapter 3, we survey the array of possible partnership arrangements, review the dynamics involved in a collaborative relationship, and discuss the management issues that must be addressed if the partnership is to be effective and mutually beneficial.

The conclusion reviews our earlier discussion, summarizes benefits and risks, and raises some issues that must be considered as partnerships between higher education and industry mature. As we complete our transition to an information society, it is more important than ever that we understand why higher education and industry must depart from their past isolation, recognize new forms of interdependence, and search jointly for innovative solutions in the future. To do so, we must look beyond the horizon of the ordinary and the habitual. The contemporary poet Richard Wilbur encourages us to step beyond these limits when he writes,

All that we do
Is touched with ocean, yet we remain
On the shore of what we know.

This book seeks to extend the shores of what we know about partnerships in the hope that higher education and industry will form mutually beneficial alliances.

"Microprocessors and silicon chips notwithstanding, an information society's critical resource is not the machine but the individual; its investment is not in hardware but in education. These priorities have important consequences for the partnership between industry and higher education, whether conceived of as a research partnership or as a partnership in education and training."

Chapter One
A New Setting for Partnerships

Of Tailors and Technology

EACH MORNING on Seventh Avenue in New York City, in the heart of the garment district, an employee comes to work, puts on his white work coat, and steps up to his work table. On the table he unrolls the bolt of cloth he is to work on that morning. After he has smoothed the cloth out on the table, he examines it to see if there are any imperfections in it. Hovering over the table is a device that looks a little bit like the movable x-ray machine that you see in your doctor's office.

In fact, it is very much like that because it has in it a flashlight bulb that casts cross hairs down on the cloth. Now the tailor, in examining the cloth, sees an imperfection. He turns a few dials, and the machine, which is cantilevered over the table, moves automatically until the cross hairs shine directly onto the imperfection. Then he presses a button on the side of the machine, and the computing machine that is connected to this device memorizes the geometric locations of that imperfection.

Then he sees another imperfection, and he turns the dial until the cross hairs shine down on it. He presses the button, and the machine memorizes the location. When he feels he has identified all of the imperfections in the cloth, he looks at the order form he has, and he sees he's being asked to cut, say, a man's size-40 regular suit. He keys that information into the system.

All of the rules, formulas, and algorithms for taking the standard man's suit pattern and adjusting it to whatever the order is reside in the memory of the machine, so it calculates what the pattern ought to be. Then the computing machine lays the pattern out on that cloth, which

> guarantees that the pattern never intersects any of the imperfections that the tailor has already identified to the machine and allows for the proper matchings on the cloth. The system insures that the minimum length of the bolt of cloth is used in the process. When that is done, the tailor presses a button, and a laser beam comes out of the device and cuts the cloth.
>
> When that gentleman goes home at night and someone asks him what he does for a living, he says, "I'm a tailor."
>
> And he *is* a tailor. But in very dramatic ways, through the information technologies that we use in our institutions, business, industry, government, and certainly, education, we have started to change the way people work, the way people live, their vocations and avocations, the way they think, and in many cases, the way they speak.

Louis Robinson's description of this New York tailor demonstrates how high technology has changed nearly all of our lives. However, it also suggests how we ourselves often do not recognize the full implications of this transformation. Like the tailor, we accustom ourselves to the technological devices we employ. We do not think twice about referring to our work in traditional terms. This tailor, however, does far more than cut a bolt of cloth. Although the final product remains a man's suit, the manner in which he processes information entails nothing less than a redefinition of his job and its relationship to others.

The garment district on Seventh Avenue may at first seem somewhat removed from the high-tech glamour of "Silicon Valley," located south of San Francisco, and Route 128 near Boston. Nevertheless, the change from an industrial society to an information society does in fact influence every aspect of our lives. Broad in scope, this change has also been exceedingly rapid. Had the automobile industry progressed at the same rate as the computer industry, "today's Rolls Royce would not only cost just $2.50 but would get half a million miles per gallon" (Botkin, Dimancescu, and Stata 1982, p. 27).

These figures are heady stuff, yet rarely do we appreciate the enormity of the change they describe. In an effort to create continuity in our daily lives, we tend to screen out the full impact of change; we continually search for traditional common denominators. This phenomenon itself is not new. In his seminal work *The Structure of Scientific Revolutions* (1962), Thomas Kuhn documents how traditional views of the world survive long after major shifts in scientific knowledge have rendered them obsolete. We continue, for example, to validate our experience of the world in Newtonian terms in spite of the revolution in relativity theory and quantum mechanics. In this respect, we are not unlike those who tenaciously held to a geocentric world view long after Copernicus had proved them wrong.

We are in the midst of a similar revolution, one that concerns how our industrial and educational institutions must adapt to the changes introduced by high technology and our transition to an information society. The scope of this transformation rivals that of a "Copernican shift." Time, however, may not be so generous with us. The pressures that high technology brings to bear on education and industry do not allow us the luxury of perpetuating the status quo. Evidence of our unwillingness to recognize the early signs of change is painfully apparent as both industry and education now seek to make up for lost time. "The problem," warns John Naisbitt, "is that our thinking, our attitudes, and consequently our decision making have not caught up with the reality of things. . . . The level of change involved is so fundamental yet so subtle that we tend not to see it, or if we see it, we dismiss it as overly simplistic, and then we ignore it" (1982, p. 13).

This first chapter describes, in general terms, the emergence and impact of high technology in an economic, social, and educational context. It also provides background concerning ties between higher education and industry by reviewing the history of their relationship and the potential and need for partnership today. Although the man working in the garment district may still say, "I'm a tailor," higher education and industry can ill afford to repeat the answers of the past without a far better awareness of the challenges that draw them into closer partnership.

High Technology and the Information Society

THE TRANSITION we are involved in has been variously described as a shift to a postindustrial society, an information society, and a knowledge-intensive society (Bell 1973, 1979; Botkin, Dimancescu, and Stata 1982; Naisbitt 1982; Toffler 1980, among others). In order to articulate the implications of this shift, many writers place it in the context of shifts through earlier stages or eras, such as the agricultural or preindustrial age, and the industrial age. The comparative scheme developed by Daniel Bell (1979) provides an extremely useful summation of these ages and the implications that surround periods of transition (see table 1, pp. 14-15).

A New Transition, A New Strategy

Commenting on the current shift, James Botkin, Dan Dimancescu, and Ray Stata emphasize that it is a change not merely in degree but in kind: "The incongruities in national policy, particularly with regard to the role of education, can at least in part be explained by the fact that our society has failed to grasp the full significance of the transition that is now under way. We are moving from a capital intensive, physical-resource-based economy of the first half of this century to a knowledge-intensive, human-resource-based economy in the last half. The formulas, policies, economic theories, and conventional wisdom that facilitated the earlier transition from an agrarian to an industrial society are no longer applicable to the transition now in progress from an industrial society to an information society" (1982, p. 5).

The new shift requires, in short, a new strategy. And it is in the context of such a strategy that partnerships between industry and education assume their proper significance. Before we proceed further, however, it is important that we specify what we mean by an information society. We can articulate the nature of this transition from several perspectives. It is a shift from products to services, or more specifically, the service of creating, processing, and distributing information. Likewise, it is a shift from physical resources to human resources, from financial capital to capital viewed in terms of knowledge, and from a domestic economy to a global economy.

Summarizing the key aspects of this transition, Daniel Bell stresses that "the crucial point about a postindustrial society is that knowledge and information become the strategic and transforming resources of the society, just as capital and labor have been the strategic and transforming resources of industrial society. The crucial 'variable' for any society, therefore, is the strength of its basic research and science and technological resources—in its universities, in its research laboratories, and in its capacity for scientific and technological development" (1979, p. 26).

To allay any misunderstanding, we might note at this point that everyone needs some kind of information and knowledge to do a job. Farmers and industrial workers must be well-informed about the tasks they perform. The difference is that, in an information society, creating, processing, and distributing information is frequently itself the job.

The shift to an information society has been underway for nearly 20 years. Careful measurements show that it officially began in 1955—the first year when more people worked in information jobs than in manufacturing jobs (see figure 1). Employment profiles indicate that in 1979, 72 percent of American workers were employed in service and information jobs, 25 percent in manufacturing, and 3 percent in agriculture. Nonetheless, our traditional notions about corporations and their products dim our perception of this change: "Most Americans still equate the nurturing of new economic power and growth with industries based on a prior generation of manufacturing technology, like cars and General Motors, or on traditional exploitation of raw materials, like oil and Exxon. This is mirrored in most senior corporate management meetings. Discussions still focus primarily on investments in physical

The Postindustrial Society: A Comparative Scheme

Modes	Preindustrial
Mode of production	Extractive
Economic sector	Primary Agriculture Mining Fishing Timber Oil & gas
Transforming resource	Natural power—wind, water, draft animal-human muscle
Strategic resource	Raw materials
Technology	Craft
Skill base	Artisan, farmer, manual worker
Methodology	Common sense, trial & error, experience
Time perspective	Orientation to the past
Design	Game against nature
Axial principle	Traditionalism

*Broadly, data processing. The storing, retrieval, and processing of data become the esser resource for all economic and social exchanges.

†An organized set of statements of facts or ideas, presenting a reasoned judgment or experime result, that is transmitted to others through some communication medium in some systematic f

Industrial	Postindustrial
Fabrication	Processing & recycling services
Secondary Goods producing Durables Nondurables Heavy construction	Tertiary Transportation Utilities Quaternary Trade Finance Insurance Real estate Quinary Health Research Recreation Education Government
Created energy—electricity, oil, gas, coal, nuclear power	Information*—computer & data transmission systems
Financial capital	Knowledge†
Machine technology	Intellectual technology
Engineer, semiskilled worker	Scientist, technical & professional occupations
Empiricism, experimentation	Abstract theory: models, simulations, decision theory, systems analysis
Ad hoc adaptiveness, experimentation	Future orientation: forecasting & planning
Game against fabricated nature	Game between persons
Economic growth	Codification of theoretical knowledge

SOURCE: Reprinted by permission of the *Harvard Business Review*. An exhibit from "Communications Technology—For Better or for Worse" by Daniel Bell (May/June 1979), p. 26.

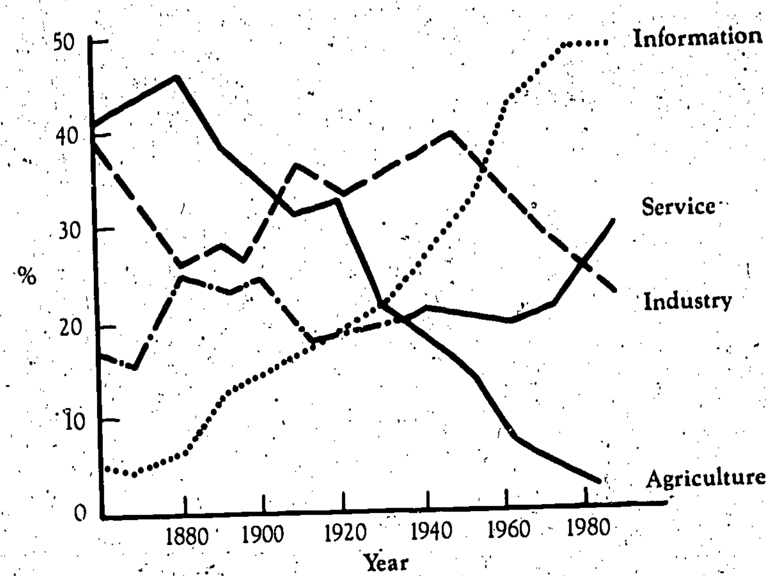

Fig. 1. The Growth of Information Occupations: U.S. Work Force 1860-1980. [SOURCE: Marc Uri Porat, *The Information Economy*, vol. 1 (Washington, D.C.: Government Printing Office, 1977), p. 121.]

plant and machinery rather than, for example, on investments in human resources. It is easier to allocate money for renovating a building than for upgrading an employee's capabilities. Tangible assets are more valued than intangible ones. Products still take priority over people. These are truisms of an old industrial order" (Botkin, Dimancescu, and Stata 1982, p. 18).

Having conceived of our old economy as producing goods, we may find it logical to think of the new economic order as providing services. However, if we look more closely at service occupations, we find that the great majority of workers are actually involved in jobs that deal with the creation, processing, and distribution of information. If we subtract these information workers, we discover that the size of the traditionally conceived service sector has remained steady at 20 percent of the work force. The actual increase has been in information jobs.

High Technology: What Is It and Who Does It?

How do computers, microprocessors, and silicon chips fit into this transformation? Are they symptoms of the change or its tangible results? They are in fact neither. Commenting on the fundamental correlation between the advent of high technology and the dawning of the information age, James Botkin stresses that the shift to a knowledge-intensive society "is *driven* by high technology." Precisely what do we mean by "high technology"? The abuse this phrase has suffered in recent years should be evident to anyone who has noticed how advertisers eagerly associate this designation with anything the least bit modish or flashy. It would be difficult to find a more useful and prudent definition than the one offered by the authors of *Global Stakes*: "'High tech,' as the term is often used in shorthand, refers to the application of science to products that are at the state of the art in terms of their function and design. Note that high technology connotes these two attributes—it is *applied* science as well as *state-of-the-art* knowledge" (Botkin, Dimancescu, and Stata 1982, p. 20). When speaking of high technology, we have this definition in mind. It implies a close correlation between applied science and advanced scientific research and suggests, by extension, the necessity of close cooperation between industry and higher education.

Robert Premus, a staff economist for the Joint Economic Committee of Congress, offers a definition of high-technology *industry* that reflects this correlation: "High technology industries consist of heterogeneous collections of firms that share several attributes. First, the firms are labor-intensive rather than capital-intensive in their production processes, employing a higher percentage of technicians, engineers and scientists than other manufacturing companies. Second, the industries are science-based in that they thrive on the application of advances in science to the marketplace in the form of new products and production methods. Third, Research & Development inputs are much more important to the continued successful operation of high technology firms than is the case for other manufacturing industries" (U.S. Congress 1982, p. 4). If business and industry are classifed according to these definitions, "high technology" becomes the province of three different sectors: those directly engaged in the research, design, and manufacture of high-technology equipment (for example, computer hardware); those engaged in providing essential services closely related to high-technology equipment and its research, design, and use (for example, software engineering); and those employing high technology (for example, robotics) in the manufacture of "low-technology" goods.

Although Premus's definition is useful, and the role of high tech in the above three industrial sectors appeals to common sense, naming specific companies that can be designated as high-technology industry is by no means a straightforward task. Writing in the *Wall Street Journal*, Eugene Carlson notes that the deluge of high-tech location studies unleashed by economic-development officials in various regions of the country are based on widely varying definitions of high technology. Each report has in turn its own method for measuring the economic effects of high technology on states and regions. Moreover, there is no single set of statistics that tracks these industries and "no one has declared where high tech stops and where, forgive us, medium tech starts" (1984, p. 33).

A recent article in the *Monthly Labor Review* observes that three factors underlie most definitions of high-technology industry: (1) the utilization of scientific and technical workers, (2) expenditures for research and development, and (3) the nature of an industry's product (Riche, Hecker, and Burgan 1983, p. 51). When used singly or in combination, these definitions produce a widely varying list of high-tech industries. This enables a host of states to declare that they are winning or at least competing well in the high-technology sweepstakes. But as Carlson (1984) rightly cautions, listing the top high-tech states depends a lot on definitions.

It is not for us to add one more definition of high technology or to set about clearing the air. What is important to emphasize is that definitions do vary, thus rendering statistics and reports somewhat difficult to evaluate. We can agree, however, that the impact of high technology is felt in many areas of the economy, that it has become a driving force in economic and social change, and that the correlation between applied science and advanced scientific research is drawing higher education and industry into closer partnership. Unmindful of these fundamental changes, we have experienced a difficult period of transition, with some dramatic economic consequences.

Our Changing Economy

"TWO DECADES ago a Russian dog named Laika went into orbit, and America responded by launching an unparalleled age of technology. These were the years when U.S. defense and aerospace industries developed extensively, and industry and academia formed a relationship that, though it did not lead to the altar, might be described loosely as 'living together'." Recalling for us a time when our economic future seemed bright and unproblematic, Pat Hill Hubbard stresses the significant contribution made by cooperation between industry and higher education. She proceeds to note, however, that "by the late 1960s, education and industry had all but moved to separate residences." For a variety of social, political, and economic reasons, law and business replaced engineering and sciences as favored career choices among students.

The profound effect of this separation between the corporate and academic communities is still with us. Between 1960 and 1980, industrial emphasis on long-term research began to be replaced by short-term product development. Hubbard notes that while R&D expenditures as a fraction of the U.S. GNP decreased by 19 percent, Japan's increased by a like amount. Our balance of trade began to shift to the wrong side during the 20-year period between 1960 and 1980. In 1960 the total value of U.S. imports was only 5 percent of the GNP. Today it is 13 percent. In 1960 we exported 25 percent of the world market share of manufacturing products. Today we export only 17 percent. Japanese productivity is, on average, four times higher than our own. For example, it takes 31 hours for a U.S. worker to build a car, while it takes only 11 for the Japanese—only 9 if they use robots.

For Hubbard and many others, the reasons for our decline and Japan's ascendency are clear. "Japan seems to have its national priorities in order, and high on their list is cooperation between government, industry, and education. We ourselves do not seem to have such a national priority or policy, except perhaps in the area of defense. As a result, a renewed courtship is taking place today between industry and academia—a courtship of necessity."

The necessity to which Pat Hill Hubbard refers is in large measure an economic necessity. It is not uncommon for businessmen and educators to preface their discussions about industry-university cooperation with a litany of economic woes faced by both communities. Several issues influence the environment in which this courtship between industry and academia is taking place. Four in particular deserve our attention: (1) the diverse nature of the corporate world, (2) the distinction between sunrise and sunset industries, (3) the transition to a global marketplace, and (4) the possible solutions presented by reindustrialization and a structural readjustment of our economy.

The New Corporate World

Our recognition of the coming information society has been hampered in large part because we perceive the economy in terms of an outmoded corporate structure that is no longer the rule in today's business environment. The diverse nature of the corporate world introduces distinctions that are often lost on those outside of the business community, particularly those from educational institutions. Industry is far from monolithic; its needs do vary. We repeat what is essentially a truism only because we remain so forgetful of it. The frequent misperception that corporations are all the same is matched only by similar ones about the organization and diversity of our educational system. Our institutions adapt to new conditions at what often seems to be a glacial pace. However, our own outmoded perceptions about them often emerge as even more obstinate, tenacious, and inimical to change.

Harold Hodgkinson illustrates how needs can vary by pointing out the breadth of corporate diversity. At one end of the spectrum are corporations with a low degree of diversification. They tend to produce products closely related to one market. Other corporations are diversified within one general sector of business and, as a result, draw upon a common pool of technologies. Moving on this spectrum toward further diversification, we find that companies become unrelated to any one market or technology. The only common denominator is that one firm is in charge. At the far end of the spectrum is the holding company. Essentially a bag of assets, a holding company is not associated with any product or market, nor can one speak of it as having any particular identity. This range of diversification can be found in virtually every sector of the economy. Moreover, the trend among corporations is toward greater diversification.

Another means by which we can understand the diverse nature of industry are Standard Industrial Classification (SIC) codes. They indicate the enormous range of products and services that business and industry are involved in. The codes are in essence a sorting device, a screen through which one can pass a host of companies when looking for certain characteristics. By employing these codes in combination with Standard Occupational Classification (SOC) codes, one can determine, for example, those industries in which scientists and engineers account for more than 10 percent of the work force or those that are particularly research-intensive. These devices enable one, in short, to become aware of clusters of industries that are likely to have similar characteristics and needs. Moreover, by studying the geographic distribution of certain groups of industries, one can better understand their impact on a local community or region. This can be of great value when trying to gauge the educational needs of industry in a particular area.

Corporations are themselves acquiring a more differentiated view of their environment. For example, many are undertaking environmental scans to track changing trends that will have an impact on them. General topics covered by such a scan include the demographic environment, the work environment, the governmental environment, the economic environment, and the societal environment. Companies then enumerate under these major headings a long list of specific concerns that bear on their operation. This greater understanding of the relationship between a corporation and its environment is akin to what Alvin Toffler refers to in *The Third Wave* as the recognition of a variety of "bottom lines," not merely financial but social, environmental, and ethical, all of which are related (1980, pp. 257-60).

Market disaggregation, says Hodgkinson, is also a factor contributing to a more differentiated corporate environment (see figure 2). At one time, for example, we thought of money in terms of one institution: banks. However, today we encounter a vast array of financial institutions and diverse means of transacting financial business. Several years ago who would have thought that Sears would be the number one lender of money in the United States? Market disaggregation of this sort is taking place in a variety of fields, including education. Large department stores provide another apt example. Originally designed to provide standardized goods to a mass market, they have now reconfigured their stores to include boutiques and specialized environments. The boom in new business starts lends impetus to these trends. Increasing from 264,000 in

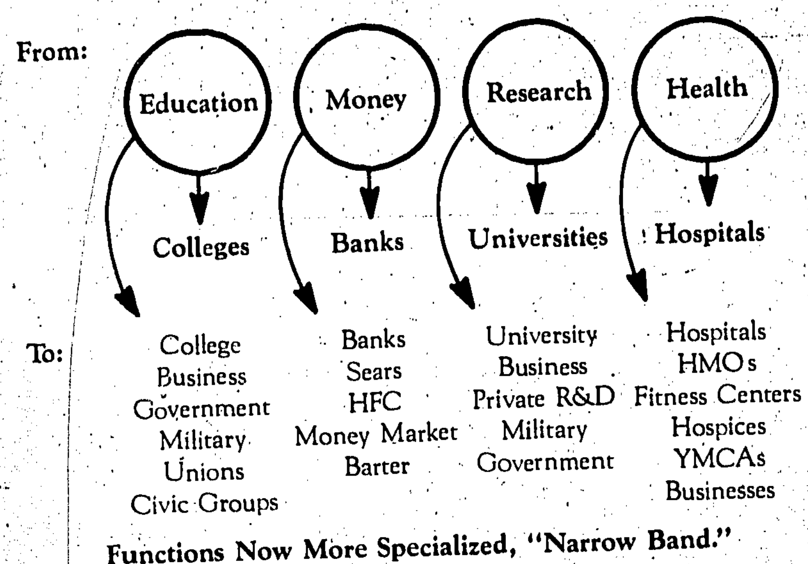

Fig. 2. Market Disaggregation. [SOURCE: Harold Hodgkinson, "Characterization of Higher Education and Industry," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.]

1970 to 587,000 in 1981, these new businesses are usually targeted to diversified and specialized markets.

This brief review conveys a sense of how diverse the corporate world really is. Corporations are structured differently, make various products, provide numerous services, and have very specific educational needs—both with respect to their employees and the firm itself. Some companies are on the upswing, others are faltering; some are quite small while others are enormous in size. There are those oriented to specific products and markets, and those that have become quite diversified. This mosaic can be rather confusing. Nonetheless, we can gain better perspective on our economic situation by employing the distinction between sunset and sunrise industries, a distinction brought on in large part by the rapid development of high technology.

Sunset and Sunrise Industries

If we are to have a successful transition from the industrial age to the information age, it is fundamentally important that we have the foresight to recognize and nurture future-oriented industries. To borrow a Japanese term, we need to move from sunset to sunrise industries. Indeed, this transition is already underway, and has resulted in what might be termed two separate economies. Our recognition of this phenomenon is fairly recent, and a short discussion may help alleviate some of the confusion we have about our economic situation.

Hodgkinson usefully analyzes this economic dichotomy by examining the performance of key industries according to their revenues in 1980. As figure 3 illustrates, the automotive, steel, and home-building industries shrank, while aerospace, electronics, retail sales, and energy expanded. The figures make clear that a new economic order is parting ways with the old. Industries that shrank have their roots in the industrial age that was at its height earlier in the century. With the exception of retail sales, a traditionally service-oriented sector, the expanding industries are essentially high-technology industries.

Taking note of these two separate economies, John Naisbitt declares that we are not, and have not recently been, in a recession. "We have parts of the country that are in prosperity and parts that are in depression, some business sectors that are doing very well, and some that are depressed. Economists have averaged the two together and declared the nation in a recession. . . .We lose all intelligence by averaging: to understand the U.S. economy today, we have to look at the economic health of each of the states and each of the business sectors" (1982, pp. 71-72). Reflecting on the reasons for our confusion, Naisbitt observes that "economists continue to root their judgments in the old indexes, and most of those are buried in the dying industries. We need new concepts and we need new data if we are to understand what is going on today, to say nothing of what may go on tomorrow" (p. 72).

When viewed in static terms, our economic situation can only baffle us. Instead, we should perceive it as the overlap between a declining sector and a newly emerging sector of our economy. The so-called Kondratieff cycle is one of the ways of explaining this phenomenon. Named after one of its first discoverers, the Russian economist Nikolai Kondratieff, this theory seeks to explain why

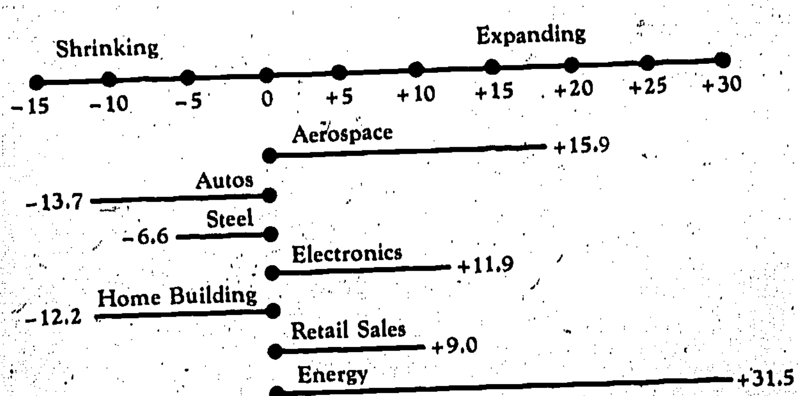

Fig. 3. Performance of Key Industries (by Revenues, 1980). [SOURCE: Harold Hodgkinson, "Characterization of Higher Education and Industry," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.]

economic vitality waxes and wanes in 50-year cycles—the so-called Kondratieff long wave (Mass and Senge 1981; Forrester 1978, 1979; Dickson 1983). We are currently between two such waves, one of which is receding and the other which is now developing. If we set our sights on the receding wave of the old order, we find our nation to be in a state of decline. Yet if we look to the developing wave, which is closely associated with high technology, we find ourselves to be in a period of vigorous growth.

More is at stake, however, than simply one Kondratieff cycle. Driven by the advent of high technology, the transition to an information society is a shift of epochal dimensions, one that extends well beyond any one economic cycle. This is not to say, however, that the current transition in our economy presents us with only two alternatives, expansion and decline, with no hope for any middle ground. High technology is not only the promise of those industries that are currently undergoing rapid expansion. It can also be used wisely and selectively to transform the fundamental characteristics of certain older industries and enable them to participate in the new economic order. Many of our older, basic industries can benefit from high technology, as can our already efficient system of agriculture. For example, it's not just robots that can have a major impact on the auto industry. In 1980, Toyota's use of computers required only ten accountants in their receivables department. An American auto division of equal size required over 300. Partnerships between industry and higher education present us, then, with two challenges: to continue the growth of high-technology industries, and to transform those sunset industries that can reasonably expect to have a bright future. These challenges require that we maintain the technological edge of scientists and engineers and that we retrain displaced workers from older industries so that these individuals can play a productive role in our new economy.

Two significant differences between sunset and sunrise industries are the emphasis they place on research and development, and how they perceive capital investment. Only recently have we understood that research and development can have a long-term economic impact. As a fraction of our federal budget, research and development decreased 36 percent between 1968 and 1980 and basic research decreased 27 percent. Research and development as a fraction of the Gross National Product decreased 19 percent. During the same period, research and development went up 14 percent in the Soviet Union, and 16 percent in West Germany, and 19 percent in Japan. Placing these recent trends in a broader historical context, Louis Robinson observes that between 1870 and 1950, there was a difference of only .6 to .8 percent between the annual growth of U.S. productivity and that of the United Kingdom, West Germany, and Japan. "This small difference, compounded over 80 years, was the decisive difference that made the United States the economic and political leader in the world." Recalling that from 1979 through 1981 we actually had a net decline in productivity, Robinson asks us to imagine "what this world would be like in only another 10 years if we should have productivity differences, not of .6 percent, but of 3, 4, and 5 full percentage points, compounded, vis-a-vis the rest of the world."

High-technology industry is one sector of our economy that recognizes the importance of research and development. Although our overall investment in industrial R&D has fallen by 25 percent since 1965, it has increased dramatically for high-tech companies. In terms of the percentage of sales allocated to R&D activities, all of the top 10 U.S. R&D companies are in the information-technology industry (Botkin, Dimancescu, and Stata 1982, p. 23).

Another useful point of comparison is the manner in which sunset and sunrise industries perceive capital investment. While it is true that all companies require capital for investment in equipment, machinery, and other goods, high-technology industry requires this to a lesser extent than other industries. Even when this investment is in new technological hardware that can be highly beneficial, rapid technological change can often render this equipment obsolete. Investments in human resources can be more productive precisely because they can be self-renewing. For this reason, the development of human resources has an importance for high-technology companies that exceeds capital investment in the traditional sense of the term. Botkin reminds us that the knowledge intensity of this industry is unprecedented. "One-third of the work force requires college degrees, about half of which are technical degrees. Another third requires associate degrees. To put it another way, a high-tech work force has 10 to 12 times more R&D, 5 times more scientists and engineers in non-R&D functions, and 70 percent more skilled workers than traditional manufacturing companies."

Microprocessors and silicon chips notwithstanding, an information society's critical resource is not the machine but the individual; its investment is not in hardware but in education. These priorities have important consequences for the partnership between industry and higher education, whether conceived of as a research partnership or as a partnership in education and training. It is precisely this premium on knowledge and education that lies behind such terms as knowledge-intensive industry and the information society.

The Global Marketplace

When stopping at a traffic light, we frequently realize that Toyotas, Hondas, and Datsuns outnumber Fords, Chevys, and Chryslers. Finding a radio or television set made in the U.S. is no longer an easy task. Indeed, there is perhaps no better indication of the transition to a global marketplace than the fact that we now consider these Japanese products to be household names and an integral part of American culture.

More than any other development, the rapid emergence of high technology forces us to recognize that fundamental shifts in our own economy go hand in hand with underlying changes in the world economy. "Unlike agriculture and manufacturing," observe the authors of *Global Stakes*, "the new knowledge-intensive industries were born global, and their direction and fate will be determined more by international developments than by any single national policy" (Botkin, Dimancescu, and Stata 1982, p. 24). While we find most other industries in a defensive posture to protect their internal markets from erosion to imports, high-technology industries place strategic importance on the global marketplace and international competition. Indeed, in the midst of ever burgeoning trade deficits, high-technology companies represent the fastest growing sector of our export economy. It is not uncommon for these firms to have one-third to one-half of their sales go to customers outside of the country. This contributed $6 billion to the U.S. balance of payments in 1980. If we include all R&D-intensive products and services, our balance of trade surplus has tripled between 1967 and 1977, from $8.8 billion to $27.6 billion (Botkin, Dimancescu, and Stata 1982, p. 23).

The positive performance of high technology in the global marketplace is no doubt encouraging, but we must recall that on the whole we have fallen seriously behind in international trade. Since 1960 we have increased the volume of our manufactured exports 11 times. During the same period, Germany has increased its exports 17 times and Japan increased its 31 times. European and Japanese executives have long considered success in foreign markets to be a matter of survival. Until just very recently, most American firms have perceived it to be merely an added benefit or even irrelevant. George A. Keyworth, science advisor to President Reagan, confesses that "our mistake was in taking our industrial superiority for granted. We assumed our lead was insurmountable and that upstart economies would, at best, carve out some small market niches that we did not want to bother with because we assumed that the profit was low—small cars are an example—or that they would take over some undesirable, less-intensive manufacturing that Americans had outgrown. We are finally beginning to recognize the seriousness of our situation" (1982, p. 609).

Changes in the international marketplace involve several factors. Our economy is no longer as self-sufficient as it once was but has become part of an interdependent global economy. As a consequence, no one national economy will have the dominance that we once enjoyed. We are in the midst of a worldwide redistribution of labor and production. As Third World countries compete more effectively, the developed countries find that they must engage in a process of deindustrialization. Even the Japanese, who seem so invincible, are relinquishing their steel and shipbuilding markets, and are turning their sights toward the manufacuture and export of the latest generation of high-powered computers. Clearly, the international pecking order has changed. Production sharing and international subcontracting are also the order of the day. Automotive manufacturing, for example, is rapidly becoming an international smorgasboard, with engines being produced in one country, transmissions in another, nuts and bolts in still another. Clearly, acknowledging and making use of international markets must be a cornerstone of our economic strategy.

With Japanese superiority so evident in the automotive and consumer electronics industries, James Botkin ponders whether our economic and educational systems can adapt quickly enough to a changing world: "The amount of time available is both short and beyond our control. It depends on international competition. Textiles, shoes, jewelry, and other labor-intensive industries have already moved to Europe and the Far East. Could this happen to knowledge-intensive industries like computers? Even the loss to Japan and East Asia of transistor radios, T.V. sets, and hi-fi equipment is not so alarming. Our best people were never enlisted in the fight for consumer electronics. But computers, communication equipment, semiconductors, and instruments are a different story. The same is true of biotechnologies, genetics, and the new materials sciences. This is our game—very sophisticated, state-of-the-art high-technology products which challenge our best-educated and most skillful work force."

Botkin continues by warning us that we cannot afford to lose this game, for there is no place else to go. "Not only are these products important in their own right as a source of employment and exports, but they are needed to modernize other industries—through automation, robots, quality control, inventory management, and sophisticated information systems." America has historically enjoyed an awesome technological lead. Our lead, however, has shortened as other developed countries turn to high technology as the only way they can compete against low-cost labor in less-developed countries. "It's not that we are getting worse," says Botkin. "They are getting better. We have to compete on a fast track. We no longer have the high-tech field all to ourselves."

Our response to these economic changes has been fragmentary, at best, and largely uninformed by a national economic strategy. Two frequently suggested policy alternatives—massive reindustrialization and structural adjustment—also exact, however, an economic and social price.

The Economic Alternatives

How can we reverse our economic tailspin? Reindustrialization, we are told, is the answer—a major reinvestment in technology that would improve the competitive position of America's traditional industries. This course would seek to improve our manufacturing capability by following the lead of the Japanese and revamping the *technology* of manufacturing. Stories that speak of the success of reindustrialization are not hard to find. A research partnership between Westinghouse and Carnegie-Mellon University, for example, has produced a new generation in robotics technology. On the other hand, there are those, among them John Naisbitt, who warn that "it is too late to recapture our industrial supremacy because we are no longer an industrial economy" (1982, p. 56). Conditioned by our old economic order, our instincts would have us invest heavily in the steel and auto industries to make them once again competitive. Naisbitt considers this reindustrialization scenario seriously flawed for two reasons. "First, the United States itself changed and our economy is no longer based primarily on industry. Second, the rest of the world has changed too; no amount of modernization can return us to our previous position. Rather than reinvest in the industries that once made us great, we must move beyond the industrial tasks of the past, toward the great new enterprises of the future" (p. 58).

Naisbitt's admonition notwithstanding, the infusion of high technology in certain traditional industries has made them more competitive. Computer-aided design and manufacturing (CAD/CAM) and robotics have contributed to important advances in the technology of manufacturing. Our newest automobile assembly lines, for example, rival those of the Japanese in their productivity and efficiency.

Another much discussed alternative concerns the structural readjustment of our economy. This policy might be described as promoting, or at least staying out of the way of, sunrise industries and allowing traditional industries to die a natural death. An alternative to reindustrialization, structural readjustment means picking winners by concentrating on emerging industries such as computers and electronics. Such a policy would encourage us to focus on the needs of the *next* long wave, a view seemingly at odds with politically popular strategies to stimulate the *existing* industrial base. In essence, structural readjustment asks us to recognize the powerful economic forces already leading us toward an economic resurgence.

Few would dispute the real economic potential that high-technology industry holds. However, questions persist whether high tech is in and of itself a sufficient answer. Although lucrative, its potential for growth is nonetheless limited. We must remind ourselves that not everyone can be a computer programmer. Just as important as encouraging growth in the high-tech sector is utilizing this knowledge effectively in other industries. For example, Lynn Browne argues convincingly in a recent article in the *New England Economic Review* that the Great Lakes states are unlikely to improve their economic condition by modeling their efforts after Silicon Valley or Route 128. "If high tech can save the Great Lakes, it will be through helping traditional industries meet the challenge of foreign competition more successfully" (1983, p. 32). A lasting cure to our economic woes will need to be broadly based. Hence the importance of incorporating manufacturing and service industries in the high-tech revolution.

It would be unfortunate were we to think of reindustrialization and structural readjustment as mutually exclusive alternatives. Both are possible. In pursuing a dual-track policy, however, we should be very careful not to make the same fundamental mistake that we have committed in the past: a myopic concentration on specific products and industries. In the long run, we would not be well served by dealing with high-technology industries as we have dealt with the steel and automotive industries, nor with silicon chips as we have in the past with "widgets." We must look beyond certain lucrative products and the glamour of specific industries and recognize that as we make the transition to the information society, a new resource comes into play that is fundamental to all products and all industries: education. The cultivation and utilization of this strategic resource is the essential premise upon which partnerships between higher education and industry must proceed.

High Technology in a Social Context

HIGH-TECH PRODUCTS and innovations are not the only measure of our transition to an information society. Equally important is society's recognition and acceptance of these changes. Systems of economic exchange have, in short, an important counterpart in systems of social change. Education's strategic role entails not only research, but increasing our understanding and utlization of high technology.

Society's Acceptance of Technology

In recounting a moment from an earlier period of economic transition, Louis Robinson underscores the importance of perceiving technology in a social context: "One of the great inventions of the industrial revolution was Joseph Marie Jacquard's automatic loom that weaves patterned cloth. He invented the loom in 1801, and by 1812 there were eleven thousand Jacquard looms in France. It made France, for the moment, the world's technological center for patterned, woven cloth. Weavers, however, did not like the device very much and they rebelled against it in a habit peculiar to the French. When no one was looking, they would take off a shoe and they would throw it into the loom. If you have ever seen a Jacquard loom you will understand that it did not take much more than a shoe to destroy the effectiveness of this delicate device. The French word for shoe is 'sabot'; the word 'sabotage' enters our language because of the practice and because of the revulsion that people sometimes have to new technologies when they do not understand or perceive what will happen because of their use."

The Jacquard loom is but one of many examples indicating that the implications of high technology can often remain hidden from our view. This suggests, says Robinson, some caution in interpreting its implications and reminds us that "it is difficult to view the trends and directions in technology separate from the phenomenon of the social acceptance of that technology."

Partnerships between higher education and industry can help create an environment in which science and technology can flourish in our society and, perhaps more importantly, be seen in their proper perspective. We are, paradoxically, the most technologically oriented society in history, and yet we are most suspicious of technology. Indeed, the degree of our scientific illiteracy can be described as a national scandal. Moreover, David Saxon reminds us, "the scientifically illiterate are not just blue-collar workers. They are not just people we think of as uneducated. They are our own products, indeed our own colleagues, the faculties of our universities. They are as likely to believe nonsense when it comes to scientific and technical matters as anybody else. It is the responsibility of universities to address this question of society's understanding of science and technology. We need to increase public understanding of science, of what it is that science can answer and what it can't."

Stressing the need for balanced education, Saxon encourages students in the liberal and fine arts to understand what is involved in a scientific and technological society. Likewise, students in science and engineering should recognize that a scientific education is not enough. "We need to create and foster not a diverse group of experts but those who are able to exercise reason and judgment. I would be profoundly uneasy to turn over the future to narrowly educated scientists and engineers, to people who do not understand that technology needs to be tempered by understanding and wisdom."

Writing on the editorial page of *Science*, Saxon urges us to "connect science as an intellectual activity to the same wellsprings that motivate us to study the liberal arts. If the ability to distinguish sense from nonsense is an indispensable aspect of a liberal education, and I believe that it is, then in a technological society science is an indispensable part of the liberal arts curriculum. The study of science and the study of the liberal arts have for too long been considered separate and separable activities. They are not, and at bottom they never were. It is time to bring them together" (1982, p. 845).

Technology and Lifelong Learning

In our transition to an information society, we must of necessity become a learning society. Changes in lifestyle and in patterns of education will include such new opportunities and challenges as internships, alternating periods of work and study, continuing education, and frequent career changes. Computers and high technology can be invaluable tools as we shift from discrete periods of education to a process of lifelong education and training. Entire libraries can be automated, indeed, stored in computer memory. With increased cooperation among educational institutions and the greater utilization of personal computing terminals, the day will not be far away when a student can search for a book in a library that is a continent away.

It is in this context that Robinson speaks at length about the computer as a democratizing instrument: "We intuitively think of all other machines we associate with the Industrial Revolution as being used only by the nations that have them." But the computer, adds Robinson, is different. "Once it exists anywhere, it exists everywhere. . . . It has a great leveling effect in making the entire society 'information-literate', in making information available to people where they need it and can use it. This seems to be tremendously important, and I'm not sure that we as a society yet understand what the total implications may be of this information capability."

The social impact of computers is in some respects comparable to Gutenberg's invention of movable type, which no longer restricted the printed word to the privileged. In Robinson's view, the computing machine has made "information accessible to people everywhere. That doesn't mean that everyone will necessarily have a machine, or will want or need one. It means that those who *do* have a need, who can benefit from its use, will have access to one where they work and, ultimately, where they live."

New Jobs: High-Tech or Low?

There is, however, a darker side to the power and influence that high technology will acquire as it pervades all aspects of our life. Its widespread use can create an economic condition that might be termed "jobless growth." Hodgkinson calls to our attention that in the United States 3 million farmers grow almost twice as much food today as 12 million did in 1910. About 436,000 railroad workers haul more freight today than 1.4 million workers did at the end of World War II. In Erie, Pennsylvania, General Electric is spending $300 million to expand its locomotive production capacity by 50 percent. The new system produces one motor frame a day with *no* workers. Previously it took 68 machine operators 16 days to produce a motor frame. What happened, asks Hodgkinson, to these 68 workers? Even though our economy will create 21 million new jobs by 1990, only 1 million of these can be called high-technology jobs in the strict sense of the term. "We have an economy," notes Hodgkinson, "that is turning out about six low-level service jobs for every one that could even remotely be labeled as high tech. Do we do anything about that and if so what? This is one of the central questions that business and higher education must face together."

When speaking of jobs, Hodgkinson cautions us to differentiate between percentage of growth and actual numbers (see tables 2 and 3) and to understand the skills required for a particular job. The fastest job *growth* in the 1980s and 1990s lies, no doubt, in the field of computers and high technology. But the total number of jobs in this area is small compared with the 1.3 million new janitors, nurses aides, and orderlies we will need. Hodgkinson adds that we will have nine of these for every one programmer. The demand for data-processing machine mechanics is also experiencing fast percentage growth (up 147 percent), but only about 100,000 new jobs are anticipated in the area. One million new jobs are projected for fast-food workers, kitchen helpers, and waiters/waitresses, a ten-to-one ratio.

Table 2

Most Rapidly Growing Occupations

Occupation	Percent Growth In Employment, 1978-90	Number of New Jobs By 1990
All Occupations	22.5	21,980,000
Data Processing Machine Mechanics	147.6	96,572
Paralegal Personnel	132.4	39,310
Computer Systems Analysts	107.8	203,357
Computer Operators	87.9	151,100
Office Machine and Cash Register Servicers	80.8	40,668
Computer Programmers	73.6	153,051
Aero-Astronautic Engineers	70.4	41,315
Food Preparation and Service Workers, Fast Food Restaurants	68.8	491,900
Employment Interviewers	66.6	35,179
Tax Preparers	64.5	19,997

SOURCE: Harold Hodgkinson, "Characterization of Higher Education and Industry," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.

Table 3

Largest Numbers of New Jobs

Occupation	Growth in Employment in Thousands 1978-90
Janitors and Sextons	671.2
Nurses' Aides and Orderlies	594.0
Sales Clerks	590.7
Cashiers	545.5
Waiters/Waitresses	531.9
General Clerks, Office	529.8
Professional Nurses	515.8
Food Preparation and Service Workers, Fast Food Restaurants	491.9
Secretaries	487.8
Truckdrivers	437.6

SOURCE: Harold Hodgkinson, "Characterization of Higher Education and Industry," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.

As colleges and universities try to cope with the social impact of high technology, and as funding responsibility for human-resource development is passed from one government entity to another, Stuart Bundy reminds us that the displaced blue-collar worker will be the one who suffers most: "The United States is presently undergoing what one author has described as a moulting process, the shedding of industrial feathers in order to acquire the wings of high technology. To the extent that this is true, hundreds of thousands and possibly millions of workers who have been employed in high-paying blue-collar positions are being displaced. Such positions, requiring little technical education, will no longer be available. The jobs of the future in high technology will require extensive technical preparation. The question emerging on the national agenda is this: Who shall be responsible for retraining the displaced blue-collar worker in the skills of high technology?" Cooperative agreements among colleges, companies, and unions can provide these workers with skills for the future. If this were undertaken on a national scale, "the result," says Bundy, "could indeed be dramatic."

Dumbing Down the Job

Contrary to popular belief, the use of high technology does not necessarily translate into greater technical skills (Levin and Rumberger 1983). The change from secretary to word processor, for example, does not require increased knowledge of math, science, or programming. Word-processing machines actually require lower skills levels—with spelling, grammar, and punctuation all being handled automatically. Reduced skill levels will also be the rule in drafting and in wholesale and retail trades. While engineers and executives in Silicon Valley are highly motivated to create new ideas and products, many other workers are poorly motivated clerks, assembly-line operators, and low-level technicians.

High technology, says Hodgkinson, makes it possible to "dumb down" these and many other jobs. Word processors eliminate the need for typists to spell and punctuate correctly. The clerk at McDonald's does not punch in the price of a Big Mac at the register, but rather presses the key with the picture of a Big Mac on it. This eliminates the need for the clerk to remember prices; the register even tells the correct change to give the customer. Commenting on this technology, Paul Bradley adds that "to dumb down the job, we need, paradoxically, extremely well-educated people. When the clerk pushes the picture of the Big Mac, there is a lot of work behind the scenes to make this pricing and inventory system function."

This dichotomy between the increased need for highly sophisticated technical education and technology's capacity to dumb down jobs extends well beyond the golden arches of the neighborhood McDonald's. The computer does indeed have the potential of allowing virtually unlimited access to information for a great number of people, of becoming, in short, a democratizing instrument. However, it can also dumb down jobs and significantly reduce the satisfaction workers derive from their occupations. Without broad and effective education, we may well become a nation with two societies: those who have knowledge of and access to high technology and those who do not—a division between a "have" and a "have-not" society with respect to information, interesting jobs, income, and lifestyle.

Partnerships from a Social Perspective

The advent of high technology is placing demands on society that we have not experienced before. Closer cooperation between higher education and industry can do more than address their respective needs. Their alliance can promote the broad, humanistic understanding of technology so necessary if society is to utilize it wisely. Educational institutions can fulfill this responsibility by serving as active agents in the public interest, not merely as repositories for cultural wisdom or sites of arcane research. Likewise, business and industry should perceive themselves as more than the producers and merchandisers of products. They are in a position to promote and effectively utilize human resources, for both their own economic well-being and that of the nation.

Cooperation has the salutary effect of broadening horizons. The new perspectives that it offers are particularly important in times of rapid and unexpected change such as these. The benefits of a specific alliance are easily recognized: they may lie in new research results or improved training procedures. But there is more to cooperation than simply this. While the overall, cumulative effects of partnerships may be less tangible, they are no less real or important. These alliances can contribute to our understanding of the social, moral, and philosophical ramifications of technology. Only the combined efforts of higher education and industry, and their collective wisdom and ingenuity, will be adequate to meet the new demands of an information society.

Education in a Technological World

THE STRATEGIC IMPORTANCE of education derives from the fact that knowledge-intensive industries are inherently connected to education. In the words of James Botkin, "The link between higher education and high technology is direct—so direct that when higher education falters, high tech can fall." And yet, our stake in education extends well beyond the immediate needs of industry. At a more fundamental level, it concerns society's acceptance and understanding of technology, without which the high-tech boom might just be a temporary anomaly.

Unfortunately, the response of the educational community to the emergence of an information society has been profoundly uneven. The boom in high technology is occurring at a time when most segments of education are experiencing declining enrollments, fiscal support, and academic achievement. Based on her field studies, Elizabeth Useem notes that "public education in the high-tech areas of Silicon Valley and Route 128 is actually moving in a direction opposite to the needs of industry. It is interesting, indeed ironic, that as microelectronics looks to the future as its new golden era, education looks to the past, not the present or future, as its golden age."

If Silicon Valley and Route 128 have their problems, the nation as a whole is in the throes of a crisis. Commenting on an educational system that is underfunded and overextended, the authors of *Global Stakes* note that "neither the strategic importance of education nor its close link to high technology is widely recognized and understood in America. . . . Somehow the nation has lost a strategic recognition of education that two decades ago was a national commitment" (Botkin, Dimancescu, and Stata 1982, p. 4).

A measure of our disoriented policy can be found in our plan to substantially increase military procurement without accommodating the technical manpower development required to design, build, and operate the new electronic-intensive weapons systems.

Botkin concludes that there seems to be "little coordination of our two 'war efforts.' We are waging a defensive war with the Soviet Union and an economic battle with Japan—but with the same troops, namely, our technical work force. It is far from clear which of these battles is more decisive to our long-term security. But it is clear where the resources are being spent."

Before we can discuss in detail the specific needs and interests of educational institutions and the potential for partnerships between education and industry, we need to review the changes that have occurred in our educational systems. For one, these systems have become more diverse. Second, we are acquiring a better appreciation of just how crucial educational institutions are to our social and economic infrastructure. And third, we need to take a general reading on the state of health of our educational institutions and consider the prognosis for the future.

The Diversity of Educational Systems

Just as the diverse nature of the corporate world often goes unrecognized, particularly by those outside of the business and industrial environment, the complexity of our educational system is not often understood by those outside of higher education. Those in the business world are frequently uninformed about the diverse educational options available.

The formal structure of higher education in the United States can be a confusing maze for the uninitiated. Students in high school have to make choices among institutions that differ markedly in size, program diversity, purpose, and culture. Proprietary institutions offer certificate programs as well as short-term training in specialized skills. Community and junior colleges have terminal occupational programs as well as programs that enable a student to transfer to a four-year institution. Moreover, there exist numerous alternatives among these four-year schools: regional state universities; "flagship" state universities; small, liberal-arts colleges; large, private research universities; single-sex institutions; religiously affiliated institutions; and an array of institutions addressing themselves to a specific clientele and specializing in certain programs. This kind of diversity extends to a lesser degree to graduate and postdoctoral education.

Howsoever complicated our formal educational system may seem, a whole other world of educational possibilities lies outside this realm. The phenomenon of market disaggregation applies not only to business and industry but also to education and research. Colleges and universities no longer have a monopoly on the educational market. Business, government, the military, unions, and civic groups all operate significant educational and training programs. Likewise, research universities no longer corner the market on research. Business, industry, the military, and government all carry out important programs in basic research and in research and development.

In addition to the 12.4 million students in college in 1978, Hodgkinson notes that another 12 million are learning through agricultural extension programs, 7.4 through community organizations, 5.8 million in business and industry, 5.5 million in professional associations, 1.7 million in federal manpower programs, and .6 million in trade unions. As these figures suggest, those enrolled in college do not represent the majority of those who are learning and studying in our society. In describing the adult learning market as it looked in 1979, Hodgkinson points out that over 60 million of the 98 million people in our labor force indicated a desire to take educational courses. And of these 60 million, over 40 million found themselves in a career transition likely to require new skills.

The world of corporate education is itself a significant "shadow education system." The role of employers as educators becomes a particularly significant factor when evaluating and promoting partnerships between education and industry. The existence of this world came as a shock to Paul Bradley: "Back in 1979, I visited the New York Telephone Company and met with their assistant vice-president for training programs. He proceeded to tell me that his annual budget was $24 million; in that same year the entire budget of Colgate University, my undergraduate institution, was

$21.5 million. They already had 72 hours of graduate credits registered with the State of New York for actual accreditation. Right then I got the notion that maybe I ought to take a look at this other world outside of what we call 'formal higher education'."

Further examples are not hard to find. Before its divestiture, AT&T spent over $2 billion annually on education and training. To put this figure into some kind of perspective, we might compare it to instructional expenditures at a major university. In the 1981-82 academic year, UCLA had the largest such expenditures of all American universities ($212 million), but they still amounted to only 10 percent of AT&T's education and training budget.

Does the ever-burgeoning diversity of educational opportunities signal a crisis in our educational system or a natural, indeed desirable, trend toward lifelong education? "As we become more of a learning society," reflects Gerard Gold, "it becomes progressively more difficult to decide where the university ends and the corporate world begins and where they both fit within the larger education and training system, which includes unions, public-sector agencies, professional associations, libraries, parks, cable television and other media publishers, educational brokers, alternative education organizations, and other local providers and consumers. The very boundaries of a university or college seem to disappear when corporations grant degrees, when colleges engage in more technical training, and when learners increasingly receive college credit for learning through life and work experiences outside the academy. It is not at all clear whether the blurring of these boundaries ought to be taken as a welcome opportunity or an emerging problem" (1981b, p. 9).

What many perceive to be evidence of failure can also be understood as a symptom of change. "The time is dead and gone, buried and past," notes James Alleman, "when we could graduate from a four-year institution with a degree that would prepare us with all the education we would need for a 30- or 40-year career. The hallmark of the successful employee of the future will be a willingness and motivation to pursue his or her continuing professional development." Lifelong learning necessarily involves the workplace; it is predicated upon the involvement of business and industry in educational programs, be it in cooperation with formal institutions of education or through the creation of their own in-house initiatives.

Whether these trends augur the failure of our educational system or portend the expansion of educational possibilities in all aspects of our lives, we can readily conclude that higher education must evaluate not only its effectiveness but also what increasingly appears to be the relatively narrow definition of its educational responsibilities. Higher education can perceive the existence of alternative educational patterns as competition that endangers its own existence in a world of dwindling enrollments. However, it seems better served by considering these alternative educational systems as proof of new educational markets and an opportunity to enter into creative partnerships with business and industry.

Education: A Strategic Part of Our Infrastructure

The term infrastructure brings to mind roads and bridges, various public transportation systems, and public-safety programs. Prerequisites for healthy economic growth, such infrastructures usually require substantial financial commitments and must be fostered and renewed over a long period of years. With new technologies becoming an important economic and social force, educational institutions assume even more importance within this infrastructure. They constitute a long-term contribution toward building a solid economic base and guaranteeing future innovation. Writing in *Technology Review*, Nathanial Mass and Peter Senge observe that "the fledgling key technologies . . . are already among us: alternative energy sources, genetic engineering, and powerful microcomputers. Perhaps we need not anticipate technological breakthroughs, but we must envision new social and economic conditions that would encourage the development of such promising innovation" (1981, p. 63).

Without an effective educational infrastructure, the deluge of information generated by our society could easily become another form of pollution. Today it is no longer sufficient for the university to create knowledge and pass it on to students in the classroom. Educational programs and institutions are important elements of the economic and industrial infrastructure precisely because they represent a critical link in the transfer and utilization of knowledge throughout our society.

A healthy educational infrastructure provides a natural focal point for business and industry. Recalling the days of smokestack industries, David Saxon reminds us that they located where they had access to power, rail lines, cheap labor, and abundant natural resources. The logic remains the same, even today. The difference, however, is that in place of rivers and raw materials the crucial resources are now educational institutions and the knowledge and information that they can offer. In Saxon's view, "Universities have something quite important to contribute as geographical and intellectual focal points for high-technology industries. If you look at the areas around our great universities, you will find high-technology industries developing there. I recall that the University of California at Irvine started in an absolutely open field. Now we find a substantial array of high-technology industries surrounding that campus. Our San Diego campus began in a deserted area 20 miles from the old center of town. Here too we see the development of high technology today. The university, then, does indeed function as an intellectual and geographical focal point. The people you wish to hire in high-technology industries are interested not just in the technical programs that a university offers but in its cultural and liberal-arts programs. They matter a great deal to those kinds of people." Commenting on the development of North Carolina's Research Triangle, Don Phillips concurs that "without the three-triangle universities—Duke University, University of North Carolina, and North Carolina State University—the whole concept would have never been possible; they are the cornerstones of the development."

Just as the presence of educational programs and institutions provides a focal point for business and industry, their absence creates a vacuum that is detrimental to the business climate. Reflecting on the importance of proper educational resources, Ted Mulford describes how their absence negatively affected the economic climate in Broome County, New York. "High technology in the Binghamton area has an economic impact of $1 billion or more. Its 33,000 employees generate work for another 22,000 employees in service activities. Because the employees of these high-technology industries are highly motivated to seek career advancement, they seek out higher-education facilities. Ready access to undergraduate and graduate programs is a critical factor as industries endeavor to recruit the caliber of employee they need to expand their businesses. One weakness bothered the Broome High Technology Council, however. This was the lack of continuing availability of manpower, especially at the professional engineering level. High-technology companies are only as good as their engineers, and these engineers require professional educational degree programs which are locally based." Recognizing this deficiency, business and civic leaders in the Binghamton area actively promoted the establishment of an engineering school at SUNY-Binghamton. Due to their intense efforts and the widespread support that they generated, an engineering program was approved in only 17 months, an amazing feat given the complexities of state education in New York.

The examples cited by David Saxon and Ted Mulford illustrate the magnetic effect that educational institutions and specific programs, such as engineering, can have on the economic environment, and how the absence of these programs and institutions is readily felt. Many large companies recruit on a national scale. A local supply of newly minted engineers may not be quite as important for them as it is to small, emerging companies. However, almost all would prefer a local source for master's-degree programs and short courses/conferences for the continuing professional development of their employees. Thus, the vast majority of firms need a local educational infrastructure to help them keep abreast of new technological developments. But are educational institutions in a position to provide what is asked of them?

The State of Education Today

The ability of our educational institutions—primary, secondary, or higher—to meet the challenge presented by our increasingly technological world has prompted widespread concern. The rapid emergence of new industries and new technologies is occurring at a time when most people perceive education as being unable to meet its responsibilities. Because of mounting concern over the decline in student achievement, support for schools, and the quality and availability of teachers (especially in science and math), a national reassessment of our educational systems is underway. Our economic concerns have the effect of speeding up the tempo of this debate.

Colleges face several problems that prompt their interest in collaboration with industry, among them a shortage of science and engineering faculty and inadequate facilities. Robert Rosenzweig warns us that "we are now living off of the capital that universities accumulated in the 1960s from government programs—research instrumentation, facilities, and faculty. If those aren't replenished, renewed, and renovated, that capital is going to be depleted. As senior faculty and senior scientists retire or move on to other activities, quality replacements will be difficult to find. Industrial laboratories are already incomparably better equipped than most university laboratories, where research facilities are rapidly deteriorating."

This situation is due not only to cutbacks in funding but also to a large imbalance in supply and demand. While liberal-arts students have difficulty finding employment, the call for electrical engineers and computer scientists far exceeds the number graduating from colleges and universities. The few scientists and engineers that have completed their master's degrees or doctorates are the focus of intense competition between academic and business communities. Increasing numbers of students wish to embark upon a career in engineering. Universities, however, are understaffed, and faculty are underpaid. They must operate with facilities and equipment that are both antiquated and overloaded. Concern for quality in the face of these resource constraints has forced many universities to cap engineering enrollments. Moreover, the intense demand for engineering and computer science programs has forced universities to reconsider their overall mission and evaluate their commitment to the arts and humanities and to the health of their core programs.

Concern about educational quality in our elementary and high schools has developed into a national debate. "There is compelling evidence," says David Saxon, "that growing numbers of high-school students are unprepared either for jobs or for further education. In the five-year period between 1975 and 1980, total student enrollments at higher-education institutions increased by only 7 percent, but enrollments in remedial math courses at four-year institutions increased by 72 percent. We in the universities and those in industry are, as a consequence, being forced to devote more time and money to teach young people basic skills—reading, writing, and simple arithmetic—things they should have learned in high school."

Pat Hill Hubbard comments on the high price we all end up paying. "Industry imports education, human-resource products, and frankly it pays a high price in tax dollars for doing so. And it rightfully expects to receive adequate numbers of quality products. Increasingly, the quality is less than what industry likes, and so it resorts to spending $30 billion each year to retrain, upgrade, and redo the products of our educational system. It's a cost that we cannot continue to afford. That cost is three times what federal, state, and local governments combined spend on education."

Louis Robinson shares with us some further discouraging statistics:

- Only one-third of the nation's high schools offer more than one year of mathematics or of science.
- At least half of all U.S. high-school graduates have taken no more than one year of biology, no other science, and no mathematics beyond algebra. Only one junior or senior in six takes a science course.

- Over 90 percent of the states now report shortages of math teachers at the secondary level, and about one-third of secondary-school science teachers did not major in science and are uncertified to teach it.
- Only 105,000 U.S. high-school students study any calculus at all, while 5 million in the Soviet Union take two years of it.

In her study of education in Silicon Valley and along Route 128, the two heartlands of high technology, Elizabeth Useem found elementary and high-school education in decline. In California, a shorter school day has been instituted for budgetary reasons. As a result, California students receive one and one-third years less education than students in the rest of the country by the time they graduate from high school. Moreover, the schools in these areas, as well as schools nationally, are missing a whole generation of younger teachers. Useem found that in the best Boston-area school systems, only 7 of the 158 teachers she studied were under the age of 30. No one in the science department at Lexington High School was under the age of 40. Moreover, there is some concern whether existing teachers have been able or encouraged to keep up with technological change.

The shortcomings of our educational system become even more apparent in an international context. European, Japanese, and Soviet students typically arrive at engineering schools with a solid background in advanced calculus and theoretical physics. They usually receive seven years of postsecondary education before being hired by industry. Students in America are hired after only four years of college, the first year of which is often remedial. This provides at best only two or three years of scientific and technical training.

"Neither higher education nor industry," emphasizes David Saxon, "can afford to ignore the problems of our schools. We need excellent primary and secondary schools to lay the indispensable groundwork for educating our students at the college level and for training our young people to be productive employees. If we don't do that we will never be able to meet this technological imperative, and respond to this time of opportunity and challenge."

Well aware of the current and future challenge that they must face, leaders from the business and educational communities are meeting together in an effort to address their common problems. The initiatives taken by roundtable groups consisting of business executives, industrialists, and educators are growing in number. These leaders realize that the success of partnerships between them depends on addressing not only issues in higher education but also those that concern primary and secondary schools.

Past Alliances

GIVEN TODAY'S HEIGHTENED INTEREST in partnerships between industry and higher education, we should be aware that relationships between the two have a long history. What has changed over the course of time is the basis, purpose, and extent of these partnerships. Our brief historical overview begins with the Morrill Act of 1862. This legislation established the land-grant university system and provided the basis for partnership between higher education, business, and government in the fields of agriculture and the mechanical arts. An examination of funding patterns in university and industrial research demonstrates how partnerships have waxed and waned in the past century. Today's concern about strengthening partnerships between higher education and industry has resulted in a call for a high-tech Morrill Act, one that will recognize, like the original Morrill Act, the strategic importance of education.[7]

The 1862 Morrill Act

If we look for historical precedents, we will find them, as did James Botkin, not during "the last decade, when we supported education in the name of the Great Society, social justice, and equity. Nor is the precedent from the earlier decade when Sputnik triggered the National Defense Education Act, although one could say that the Sputnik of today is the economic challenge from Japan. But more profoundly, the precedent occurred in the last century when the Morrill Act was passed, marking the major shift of our society from an agricultural to an industrial economy."

The federal act that Vermont Congressman Justin Morrill sponsored funded colleges to "teach such branches of learning as are related to agriculture and the mechanic arts." This led to the establishment of an agricultural extension program and the birth of modern farming. The extensive land-grant college system is a product of this legislation. MIT, Cornell, Purdue, the University of California, and many of our other great technical universities owe their existence to this visionary educational experiment.

Forging the interests of government, education, and the farming community into a national policy lay at the heart of this experiment. Its success is apparent to us even today. Not only did it help revolutionize farming, it ushered our country into the industrial age. Only 5 American engineering schools existed when the Land-Grant Act was passed in 1862. Twenty years later there were 85, half of them engineering departments at land-grant institutions. One-hundred years later, one out of four college students is enrolled in a land-grant institution.

The legacy of the Morrill Act is still felt today, and encourages us to explore what might be done to further the high-technology revolution. The National Commission on Research finds that "a linkage is necessary between universities and industry which will allow the latter to monitor and transfer relevant research more directly into the innovation process. To a considerable extent, this communication does exist in agriculture. The Morrill Act and the land-grant college system it spawned have resulted in agricultural experiment stations dispersed amongst the farming communities, with close ties to agricultural research departments in colleges and universities. Linkages on this scale are largely absent from the physical and biological sciences. Their establishment requires that the university researcher, and his or her industrial counterpart with similar interests, skills, and knowledge, begin to talk together. The most effective vehicle for this communication is a cooperative research program" (1980, p. 11).

The fundamental importance of the Morrill Act today lies not in its particular programs or in its funding mechanisms, but in its essential intent. Commenting on the farsighted nature of the legislation, Botkin, Dimancescu, and Stata suggest that "perhaps the most impressive legacy born of the Morrill Act was the understanding that education—open to all and focused on learning applied to real economic needs—could not be divorced from economic growth and national strategy" (1982, p. 153).

Patterns of Interaction: 1920-Present

The major American research university and the modern industrial corporation are both products of the late 19th century. A brief sketch of the history of these two institutions, however, indicates that cooperation and collaboration between the two can only be described, even in good periods, as uneven and haphazard.

Growth of American universities and progress in their research endeavors during the 1920s and 1930s can be traced, in part, to philanthropic support from individuals and corporations. Moreover, tremendous growth in student enrollments increased revenue not only from students but from state governments. It is instructive to note, for example, that U.S. university enrollment doubled every 20 years from 1900 to 1960. This period of unparalleled growth saw the establishment and expansion of many science facilities and basic research programs. However, apart from philanthropic contributions, American industry did not participate directly in this growth.

Industry's own interest in research began to grow around the turn of the century, with industrial research laboratories coming into their own after 1910 and rapidly expanding through the early 1930s. Interest in research was intense during this period, with national R&D expenditures undergoing a tenfold increase during the decade 1917-1927.

While both higher education and industry experienced rapid growth during this period, there was little collaboration. Although their paths were parallel, they were nonetheless separate. Some exceptions can be found: Caltech's association with the aircraft industry and MIT's cooperation with the petroleum industry. Nevertheless, colleges and universities remained rather isolated from industry during the 1920s and 1930s, particularly in the area of research.

World War II made it clear to government, industry, and education that a more collaborative effort was necessary. In a sense, the war can be said to have given rise to the modern U.S. research complex. The demands of wartime placed a strong emphasis on technology transfer and on the use of basic research in solving practical problems.

In the years following the war, this enthusiasm for science led many companies to embark on a program of basic research that was too broadly conceived and overly optimistic. As David notes, "There was a false start in establishing fundamental research programs by many companies in the 1950's and 1960's as a result of the 'science is wonderful' syndrome" (1980, p. 134). The government responded to the lessons it learned during the war by establishing such funding agencies as the Office of Naval Research and the National Science Foundation. As a result, the great research universities prospered, as did those industries closely allied with government interests. And yet, as David observes, these programs left out important sectors of business and industry. "A chasm remained between academic specialization and the so-called basic civilian industries including engineering as a practice. This situation lies behind today's lamentations about lack of technological innovation in these basic industries, and government attempts to stimulate research by direct funding" (1980, p. 134).

The 1960s were the period of tension between the corporation and the university campus. While industry support of higher education remained relatively constant in the early 1960s, the rapid increase in federal funds to higher education appeared to eclipse the industrial support of research and the presence of the corporation on campus. During the late 60s, the Vietnam War aggravated antibusiness sentiment on campus, thereby creating not only an unfavorable climate for faculty involvement with industry but also an unsuitable environment for company recruiting. Skyrocketing federal funds for education combined with the tarnished image of business and industry to produce a negative or, at best, indifferent attitude toward corporate involvement in higher education. While collaboration among individual scientists from industry and the university continued, partnerships at the organizational level were infrequent. In its report on university-industry research relationships, the National Science Foundation notes that "the industrial share of university R&D support dropped rapidly from just over six percent in 1960 to below three percent in 1965. It wasn't until after 1970 that the percentage rose above three percent reaching its 1980 level of 3.8 percent. However, in constant 1972 dollars industrial support for academic research doubled between 1966 and 1978" (1982, p. 7). (See figure 4.)

How might we characterize the developments of the last three decades? John Slaughter offers the following summary: "In 1953, industry was investing $19 million toward the total of $255 million spent for research and development at the nation's universities. By 1981, the total national investment had grown to more than $6 billion, with industry's share increased to $240 million. That represents an enormous increase in support for research and development as a whole, but a drop in the share of support from

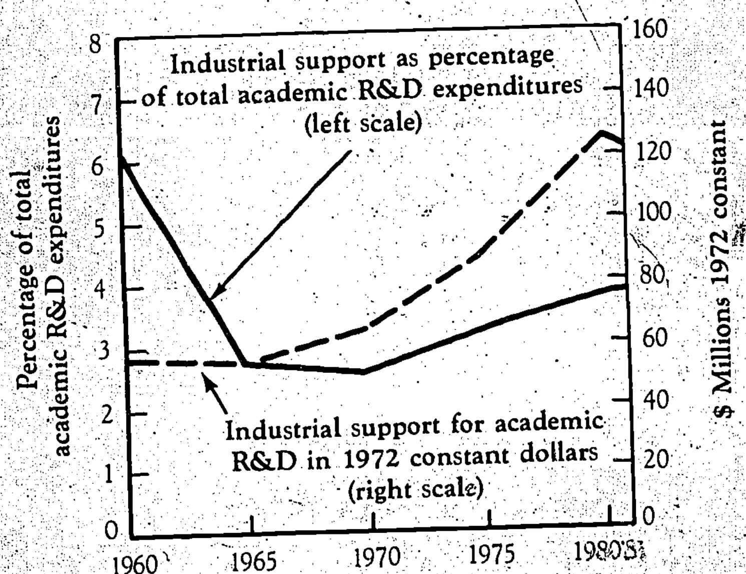

Fig. 4. Two Ways of Looking at the University-Industry Connection. [SOURCE: National Science Foundation, *University-Industry Research Relationships: Myths, Realities and Potentials* (Washington, D.C.: Government Printing Office, 1982), p. 5.]

industry from 7.5 percent to around 3.9 percent. Government, I don't have to tell you, has made up most of the balance. In 1981, government provided more than $4 billion of the over $6 billion total. But the most rapid rise in federal support of research was in the 1950s and the early 1960s. By the mid-60s, the rise in government support had begun to slow down. You know the rest. Government support for the most part is leveling off; support from industry appears to be on an upswing. The nation needs and expects industry's assistance to continue—with luck, to increase."

Taking note of the decline in government support for basic research in higher education, Ray Orbach warns, however, that business and industry will not be able to make up the difference. Even though industry has increased its support to higher education for basic research by 2.7 times since 1953 in constant 1972 dollars, the government increased its support by a factor of 12 times during that same period. The National Commission on Research reports that "the industrial share of the funding of university basic research dropped by 75 percent between 1953 and 1978. As a percentage of the basic research effort by all performers, industry's support in 1953 represented 50 percent, whereas in 1960 the figure was 20 percent, and in 1978, 18 percent" (1980, p. 7). In short, the proportion of industry's contribution to basic research in universities has fallen markedly. In the view of the Commission, it is currently "so low a percentage that, even if it were influential in setting research direction in the past, it could hardly be regarded so today. This has contributed to an isolation of industry from the university researcher in many disciplines, and made information transfer between universities and industry even more difficult" (pp. 11-12). Only recently has industry begun to reverse this trend.

Sizable reductions in federal funding of basic research have created an unstable and uncertain climate. Although the government's requirement for research and skilled workers continues to rise, it has not provided commensurate support in these areas. The severe cutbacks experienced by the National Science Foundation earlier in this decade are but one example. Although quite welcome and helpful, increased support from business and industry cannot compensate for even a 10 percent reduction in government support of basic research. Private enterprise can nonetheless provide substantial, indeed crucial, assistance by augmenting government support and buffering colleges and universities from fluctuations in public funding.

Thus far, we have viewed trends in university and industry collaboration largely from the perspective of basic research. When viewed in terms of training, continuing education, and human-resource development, collaboration between campus and corporation is a relatively recent phenomenon. Ever since the Middle Ages, when apprenticeships became integrated into the institutional structure of trade and craft guilds, industry has always perceived employee training as an in-house affair. Colleges and universities, for their part, were content to consider teaching high-school graduates as their major, sometimes sole, activity. It has only been in the past decade or so, given a broader understanding of human-resource development, that corporations have begun to turn to universities and community colleges as an educational resource. Likewise, during the past two decades higher education has become aware of the large pool of adult learners interested in furthering their education. It is only now fully comprehending that this requires close, ongoing alliances with business and industry.

Assumptions Underlying Previous Interaction

A strong and positive feature of prior collaboration between corporation and campus has been the consulting network established between individual researchers. It is largely due to this network that partnerships have existed to the degree that they have. What is striking, however, is the absence of partnerships on an organizational or institutional level. It is precisely in this area that current efforts toward partnership have much to accomplish.

We should also note the degree to which the interaction between higher education and industry during the past 30 years is predicated on a specific funding mechanism, namely, the grant. Grants rarely operate on an organizational or institutional level;

rather, their unit of structure is the individual research scientist, known as the principal investigator. This funding mechanism is one of the obstacles to developing increased ties on an organizational or institutional level. Moreover, today's uncertain funding environment has elevated the game of grantsmanship to an art. Researchers rely on the possibility, if not inevitability, that one grant will perpetuate itself through another. Meanwhile, industry's need for specific results and the timely transfer of technology goes unmet.

Earlier partners often did not understand just how crucial long-term collaboration is to innovation and technology transfer. The efforts of higher education and industry have consequently often been shortsighted. Robert Rosenzweig points out, for example, that business has acted toward universities the way government has behaved, as if the university were selling research and they could buy it off the shelf. There has been little understanding that "the end product is the fruit of a whole stream of events and processes, all of which need to be supported if you are going to get what you want in the end. Business usually takes the position that they support higher education through their tax dollars. That does not appear to be sufficient any longer." In turn, the university is discovering that its research effort is no longer complete unless it helps transfer new knowledge to society.

Although the growth of industry and higher education has frequently been parallel, this historical sketch suggests that there has been little direct interaction. Nevertheless, the assumptions and needs of one party have contributed to the assumptions and needs of the other. For example, industry's concern for efficiency and cost effectiveness was met by graduates of university business schools. Likewise, the preoccupation of our business schools with these short-term management techniques was reinforced by the actions of industry. This separate but nonetheless parallel development has perpetuated each party's misperceptions and false assumptions about the other. Partnerships offer higher education and industry an excellent opportunity to engage in cooperative strategic planning in an environment that allows them to understand each other's real, not merely perceived, needs.

Looking for Common Ground: The Potential for Partnerships Today

ALTHOUGH SCATTERED and not always highly visible, partnerships between industry and higher education have set valuable precedents; they have shown what can be done and have fueled widespread desire for greater and broader collaboration. Some educators and executives may perceive the current interest in partnerships as aberrant, a faddish curiosity sparked by a short-term need. Most believe, however, that the advent of high technology has ushered both higher education and industry into a period where partnerships are not a matter of choice but of necessity, and where collaboration proceeds not from a desire for advantage but out of a recognition of mutual benefit.

We are, as a result, better able to appreciate the visionary and farsighted principles upon which the original Morrill Act was based. Commenting on widespread interest in a modern-day equivalent of the Morrill Act, James Botkin explains that "this is not just another plea for aid to education. It is a new strategy to revitalize the American economy." While there is a need for national policy, neither higher education nor industry can afford to wait for their marching orders from Washington. Of more immediate and direct concern are actual partnerships themselves. These flesh and blood partnerships provide tangible evidence that collaboration really works and can be an effective means of addressing our problems. Because of these actual partnerships, business leaders and educators are considering new strategies and perspectives that will lay the groundwork for greater collaboration between them.

Developing New Perspectives

Preoccupied with managing decline, higher education has only recently begun to plan for a challenging and radically different future. A little over a decade ago the Carnegie Commission on Higher Education reported that "a traumatic loss of a sense of assured progress, of the inevitability of a better future, has occurred. Instead there has developed more of a nostalgia for a Paradise Lost. . . . The faith in a future that would surpass the present sustained a century of progress in higher education—from the end of the Civil War up to the time of the Vietnam War—but now no longer" (1973, pp. 6-7).

Higher education is now beginning to pull itself out of its depression, look to the future, and freshly evaluate its mission. To employ a term current among industry executives, it is now considering what business it is in. Ever since the birth of the great European universities in the Middle Ages, the mission of education has been quite separate from that of business, commerce, and industry. Surprisingly, the industrial revolution did little to change the essential nature of our educational system. The current technological revolution demands that higher-education institutions recognize that training and research have broad economic implications. Without sacrificing their traditional values or mission, colleges and universities would greatly benefit from a better understanding of their role in the larger economic environment. Such an understanding would likely prompt greater collaboration between business and education and yield new opportunities for both.

"What business am I in?" is a frequent query of those in the corporate world, but far too rarely is it seriously pondered. Many executive officers do not look beyond this quarter's bottom line or the exigencies of the next board meeting. The answers that industry seeks cannot be found by simply reacting to the symptoms of stagnation but by engaging in strategic, long-range planning and recognizing the fundamental importance of education. "The most effective policy changes," suggest Nathaniel Mass and Peter Senge, "are not likely to be obvious responses to pressing problems, but rather those that emerge from an appreciation of the longer-term causes of those problems. Successful policymakers will work *with* those forces rather than *against* them. The effort will require innovative thinking and persistent, energetic sponsorship" (1981, p. 65).

While national policy may be discussed in Washington, and initiatives taken to create a favorable climate, the alliances that really matter are forged through the collaboration of university and industry researchers and through discussions between corporate officers and university presidents. When thoughtfully multiplied across the country, these active partnerships will help protect the source of a skilled work force, define research needs that contribute to the public good, and prevent the dissemination of results from becoming just so much "noise."

Alliances are possible and necessary on two general fronts: human-resource development and research. Consider, for a moment, how recent developments have encouraged us to rethink the way we have traditionally conceived of collaboration.

Human-Resource Development

As we increase our awareness of education's important role in the workplace, collaboration between the corporation and the college campus becomes not only more important but more feasible. Many changes are evident. Corporations no longer speak of personnel administration, but of human-resource development. Likewise, colleges and universities have renewed their sense of mission: the very idea of "postsecondary" or "higher" education is gradually being replaced by the notion of lifelong learning.

To this day, however, the ideal of lifelong learning has not found fully adequate reflection in our social, educational, and business institutions. We tend to pay pious lip service to the notion and then trifle with it in practice. Our growing awareness of the need for partnerships between industry and higher education has brought us to an interesting and important juncture. Bridges are being built between the workplace and the classroom. We now have more than a vision of what is possible; we have concrete examples of collaboration that provide us with opportunities to evaluate, and in some cases emulate, actual working alliances.

Two possibilities for collaboration are continuing-education programs and "courses for hire," that is, courses offered for a particular company or organization, often on location. Many four-year colleges and universities have been fairly responsive to the market for continuing education, although few have systematically assessed the needs of individuals or industry. Community colleges have been far more responsive in providing "courses for hire" to the business community. Moreover, education would do well to consider other potential collaborators apart from business and industry, such as the military, professional associations, labor unions, museums, and health organizations.

However, collaboration requires that educational institutions become aware of the new arena in which they are functioning. When operating on their home turf, schools could afford to emphasize individual learning and to allow, even encourage, a spirit of free inquiry. However, as Robert Craig and Christine Evers point out, "A major difference between employee education and traditional education is the employee educator's emphasis on assessing needs. Most employee education and training is directed toward a specific purpose—improving job and other organizational performance" (1981, p. 40). The requirement to design programs that will meet specific needs is probably a major reason why employers make relatively low use of traditional higher-education programs and resources. Craig and Evers advise that "if higher education wants to increase employer utilization of its programs, educational institutions must make an effort to identify employers' needs and increase their responsiveness to them" (p. 40).

Employers, for their part, are finding that they must augment utilitarian training needs with a more broadly conceived educational commitment. The pace of technological change is such that corporations can ill afford to limit their programs to in-house initiatives that are job-specific and highly specialized. A healthy dose of general training and educational development can help insulate companies from unforeseen shifts in work-force requirements brought on by new technological advances. Moreover, it is readily acknowledged that greater educational opportunities increase worker satisfaction and loyalty.

Collaboration in Research

"There is no question in my mind that industry needs a renaissance in innovation, and it needs help from academia to do it." Monte Throdahl's remark acknowledges that collaboration between corporations and the university campus in the field of research is driven by our apprehension that sluggishness and inefficiency hamper our efforts to translate scientific knowledge into useful products and processes. As the National Commission on Research reports, "There is widespread and serious concern among leaders of government, the universities, and industry over the erosion of U.S. hegemony in science, technology, and rates of productivity. Much of this concern focuses on lagging innovation, on the idea that the U.S. has not maintained the innovative characteristics which fueled its earlier scientific and economic success" (1980, p. 1). We may be the undisputed world leader in the *generation* of knowledge through research, but in recent years, other countries are doing a better job of *using* that knowledge effectively in support of economic growth. Our universities are now recognizing this technology delivery problem and are generally acknowledging a social obligation to facilitate the transfer of knowledge into commercial applications.

The most effective area for research collaboration between higher education and industry lies in the realm between basic research (exploration, discovery) and technology (applying that knowledge). In other words, the common ground for collaboration concerns that shadowy, often uncharted yet ever so important region known as innovation. Figures 5 and 6 illustrate what the National Commission on Research found:

> There has always been an implicit link between basic university research and industrial innovation. . . The process of innovation and invention focuses basic research to yield useful, identifiable products. Between the area of basic research and the development area is an overlap area where feasibility of technological development is determined.

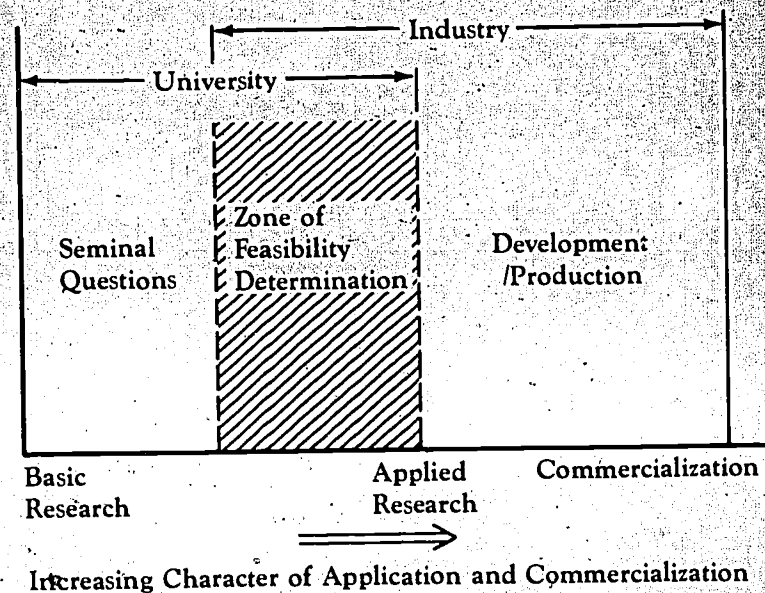

Fig. 5. Organization Involvement in the Innovation Process. [SOURCE: National Commission on Research, *Industry and the Universities: Developing Cooperative Research Relationships in the National Interest* (Pasadena, Calif.: California Institute of Technology, 1980), p. 5.]

> The portion to the left of the feasibility area is a region in which universities are preeminent and contains the greatest randomness. This area is the most unmanageable, in the sense that it requires faith in the creative genius of investigators. In this area are the seminal questions and the innovative answers.
>
> The portion immediately to the right of the feasibility area, applied research, is more the province of industry than university, though the latter may make important contributions. Proceeding further to the right, one passes to the unique province of industry. Industry is most able to bring order out of randomness—to develop and commercialize research through innovation. [P. 4]

Commenting on this division of labor, Harold Sorrows discusses how our perceptions of the innovation process have changed: "When I was in the business of new product development, there was the myth that you did some good fundamental research, and out of this came an idea. You then carried it to applied research, laboratory research, development and design, and came out with marketable products. In the 1950s and 1960s, many companies hired top-flight scientists and told them 'you just go do whatever you want to do, and we'll take it to the marketplace.' And sure enough, that did turn out to be a myth." Since then we have viewed the

1978 Billions of Dollars

	Basic Research	Applied Research	Development
University	3.0	1.2	0.2
Industry	1.0	6.0	26.0

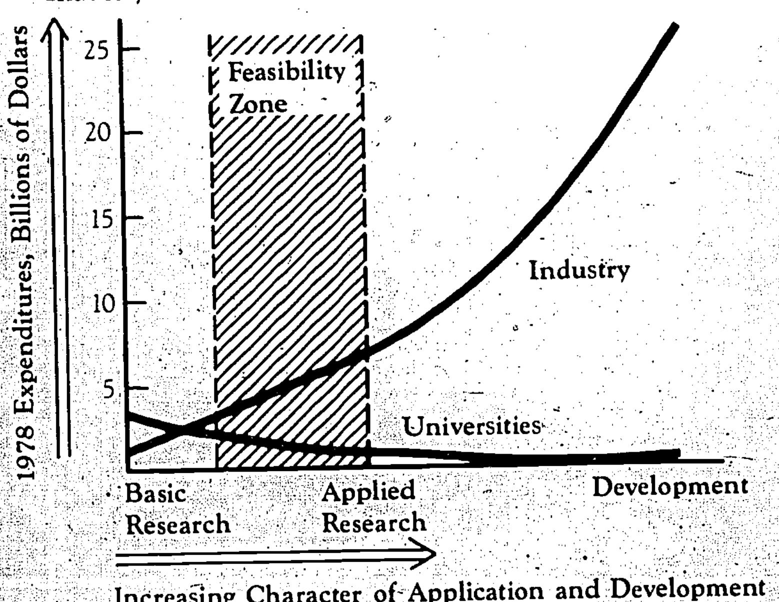

Fig. 6. University and Industry Research and Development Spending Patterns: 1978 Billions of Dollars. [SOURCE: National Commission of Research, *Industry and the Universities: Developing Cooperative Research Relationships in the National Interest* (Pasadena, Calif.: California Institute of Technology, 1980), p. 6.]

responsibilities for research and commercialization somewhat differently. "The universities do the basic research," says Sorrows, "and have prime responsibility in the scientific community. Most agree that the federal government should put up the money for this type of arrangement. In most respects, the boundary lines for this research responsibility and financial obligation are well known. At the other end of the spectrum we have marketable products. Likewise, it is well known and established that industry has responsibility for this sector."

The problem is that the process of innovation refuses to recognize these boundaries. Our efforts to nurture this process have convinced us of the need for partnerships and of the necessity to explore and utilize the interfaces between industry, university, and government—interfaces having to do with the transfer of knowledge and technology. "This transfer," adds Sorrows, "crosses a no-man's land. No one really has responsibility for this area, an area that is crucial to the efficiency of our R&D system. As a result, technology transfer has not been very efficient. . . . In my view, the purpose of industry-university partnerships is to make the transfer of technology across this no-man's land of innovation a much more efficient process."

Although conventional wisdom about the conduct of research might suggest that there should be a strict division of labor between the university research lab and industrial product development, recent advances in biotechnology have challenged these cherished notions. As Robert Rosenzweig reminds us, "These fields have been, until very recently, the purest of the pure sciences. The latest developments in biotechnology seem to bring the laboratory bench of the basic scientist tantalizingly close to the industrial production line and even to the merchant's shelf." Slowly nurtured through years of quiet basic research, recombinant DNA techniques are now suddenly yielding financial dividends.

These events have blurred traditional distinctions between basic and applied research and, by extension, distinctions between the university and the corporation. The challenge presented by biotechnology is in several respects very healthy for the university.

Advances in this field as well as in integrated circuits have helped dissolve some of the artificial boundaries that have crystallized between traditional, academic, engineering disciplines. Industrial collaboration has fostered a more interdisciplinary approach.

Such developments, however, force us to ask important questions about the relationship between disinterested research and monetary reward. In part, these questions arise because the time lag between invention and full commercial development has in some instances all but collapsed. For example, between the invention of the transistor and its widespread commercial development lay an intervening period of at least a decade. But with biotechnology, the prospect of financial gain is just around the corner. Quipped Lewis Thomas, "Cells are not just useful, they are about to yield profits" (1980b, p. 22).

Biotechnology is but one of many challenges that confront both corporations and campuses. It illustrates that we must sort out the roles, needs, and interests of our respective partners in collaboration. Only then can we look more closely at the spectrum of possible partnerships and the ways we can best foster and manage these alliances.

"A successful alliance requires that each party recognize the aspirations and fears that both bring to their partnership. Each must comprehend the legitimate needs of the other, while at the same time dealing with occasional misperceptions and inflated expectations. In this sense, discerning interests and areas of mutual concern is a prerequisite to any partnership."

Chapter Two

The Actors and Their Interests

Understanding Each Other's Role: Why We Need to Talk about Interests

INDUSTRY AND higher education increasingly find themselves in a necessary, but at times uneasy, state of intellectual and economic symbiosis. Different though they may be, both must live together and form an intimate association. As we noted in the previous chapter, the advent of high technology has provided a new setting and a new rationale for their collaboration. A successful alliance requires, however, that each party recognize the aspirations and fears that both bring to their partnership. Each must comprehend the legitimate needs of the other, while at the same time dealing with occasional misperceptions and inflated expectations. In this sense, discerning interests and areas of mutual concern is a prerequisite to any partnership. Understanding each other's role represents an all-important first step in evaluating how we should go about developing an alliance.

As Monte Throdahl observes, "It would be inappropriate to detail the needs that industry has from academia or academia from industry, as if a shopping list would do. I think we should emphasize what high-technology industry and higher education can do together." David Saxon likewise emphasizes the desirability of discussing needs and interests "in a larger context than the topic would demand—the context of a troubled nation groping for an effective course of action. As I think about our needs I also must think simultaneously about the contributions that we must make. Moreover, I want to interpret the word 'need' broadly. I want it to mean more than material needs, more than facilities and resources, more than the terms of agreements and grants. We should also see needs in terms of an essential set of prerequisites and in terms of the things we ourselves ought to do."

Misperceptions and stereotypes often interfere with our efforts at mutual understanding. Moreover, our hesitancy to discuss these barriers only perpetuates them. Paul Bradley recalls his own experience with the cultural differences that seem to divide industry and higher education: "I pursued my undergraduate and graduate studies in the 1960s, and I do not recall one good word being said about American business on any of those campuses during those years. 'Profits' was a dirty word." When Bradley crossed the chasm and moved into the business world in 1980, he discovered a new phrase. "It's called a 'damned academic.' A damned academic is anybody who comes out of the academic world; he or she is assumed to be unrealistic, theoretical, to have his or her head in the clouds, and basically not be a part of the real world. The sides of the chasm are far apart and the gulf is deep. But we can bridge that chasm."

Paul Bradley's experience in the two worlds of mortarboards and pinstripe suits calls to mind a similar discussion by the English scientist, novelist, and philosopher C. P. Snow. In his now famous 1959 Rede lecture entitled *The Two Cultures and the Scientific Revolution*, Snow observed that "we have lost even the pretense of a common culture. Persons educated with the greatest intensity we know can no longer communicate with each other" (1964, p. 60). Scientists and humanists have formed what he christened "the two cultures." In spite of their high level of education, each group's narrow training makes it nearly impossible for either one to carry on an intellectual conversation with the other. "There is no excuse," said Snow, "for letting another generation be as vastly ignorant, or as void of understanding and sympathy, as we are ourselves" (p. 61).

There seems little doubt that a culture gap has separated industry and higher education. The crucial question is whether these differences are more imagined than real. In his study of the impediments to greater partnership between the two communities, Donald Fowler noted that while both industry and higher education agree that cultural attitudes can present obstacles, he was never able to determine "whether these attitudinal factors are themselves root causes or whether they are merely symptoms or magnifiers of other, more basic impediments. However, when an attractive research opportunity presents itself to industry and to a university, and other impediments or problems can be worked out, then the attitudinal problems tend to fade away or to be easily put aside."

While many differences may result from misperceptions, inappropriate attitudes, and long-held biases, some are nevertheless quite real. As Gerard Gold observes, "If there is a corporation where Kant, calculus, Marxian economics, anthropology, engineering, basket-weaving, and yoga are taught, it is an exception to the rule, and probably a marvel. Under the aegis of higher education such a melange is merely to be expected. However, few would rely on a higher education institution to successfully launch a space shuttle, produce and market a new soap, or manufacture computers on a large scale. This distinction creates strains that inevitably are felt in the formation of serious relationships and alliances between higher education and business" (1981a, p. 3).

As is the case in a symbiotic relationship, these differences must be utilized to mutual advantage. Each can help the other pose that central question: Where is high technology taking us? A[illegible] together, both can anticipate and solve future problems. Early in this century the philosopher and theologian Martin Buber wrote, "It is more important that the machine reflect our humanness, than we become the mirror of the machine." If higher education and industry are indeed two cultures, the challenge expressed by Buber is all the more reason that they be on speaking terms. Indeed, given their different yet potentially complementary outlooks, their collaboration may provide truly adequate answers to this question.

Partnerships seem easy at the grass-roots level. You sit down with a faculty member or executive, you define the problem, you shake hands, and go out and do it. But when lawyers, the sponsored research office, and other administrators become involved, the complications grow exponentially. The interests of higher education and industry derive in large part from the history of their organizations. However, as the interests of these parties change and cohere due to the challenge of high technology, the organizations themselves may be slow to respond. History, we are told, is strewn with the dogmas of institutions that were appropriate in the past but disastrous to the future. One of the challenges facing these new alliances is to be sure that our institutions are adequate to a new world. Understanding how the needs and interests of higher education and industry are changing represents the first step toward transforming the institutional and organizational environment in which partnerships must be forged.

The Needs and Interests of Higher Education

THE FISCAL CRISIS confronting higher education may be the most obvious and pressing reason why university campuses are now approaching corporations for support, but money is not their only motive. The emergence of high technology has brought about changes in the curriculum and has often prompted a reevaluation of an institution's educational mission. These challenges are such that colleges and universities can benefit ~~from the~~ assistance and enlightened participation of business and industry. Of the many needs facing higher education, six deserve particular mention:

1. Supporting faculty and graduate students
2. Financing and utilizing basic research
3. Upgrading facilities and equipment
4. Maintaining the health of core programs
5. Developing new patterns of education
6. Adapting organizational structures

After describing these six needs, we will discuss the special role and needs of community colleges, for they are in many respects quite different from those of a major research university.

Supporting Faculty and Graduate Students

The current shortage in university engineering and computer-science faculty threatens to dry up the stream of creative individuals in these professions at its very source. This is a worrisome prospect not merely for higher education; business and industry also have an important stake in assuring that this creative stream continues to flow. Indeed, arguments encouraging business and industry to support this endeavor can be made solely on the grounds of their own self-interest and financial well being.

Concern about the scarcity of engineers prompted the

American Electronics Association (AEA) to undertake a study of the problem. Pat Hill Hubbard, Vice-President for Education of the AEA, reports that "the gatekeeping item is not a lack of qualified students. We have an abundance of highly competent, qualified students who want to study high-technology engineering. The gatekeeping factor is a lack of faculty to educate them. And industry is largely at fault here for practicing what may be called a brain drain. Education is like a Third World country that lacks the financial resources to attract its citizens back home to work."

Salary differences can be substantial. A student with a new bachelor of science degree in electrical engineering can expect to be offered a starting salary in industry of $24,000 to $29,000. Should that student choose to stay on and receive a doctorate several years later, his or her starting salary would probably be less than $24,000. Clearly, undertaking four or more years of graduate education, not to mention paying for it, involves nothing less than a vow of poverty.

The source of the problem lies in the sheer demand for engineers brought on by high technology, an explosion illustrated in figure 7. Greater demand than supply creates a competitive market, with salary differentials between industry and universities that can approach as much as 100 to 200 percent. Industry's ability to offer greater financial rewards and state-of-the-art equipment and facilities results in fewer engineering graduates pursuing Ph.D. degrees and, in turn, in fewer faculty (see figure 8). Large increases in undergraduate enrollment have created a dramatic disparity between the number of students and the size of engineering faculty (see figure 9). The problem is self-perpetuating and results in an increasingly severe faculty shortage, one that averages 9 to 10 percent but approaches 17 percent in computer science and even 50 percent in some very specialized fields (see figure 10). Of the 1,650 unfilled engineering faculty positions in the U.S., over half have been vacant for at least one year. In the past five years, for example, 38 of the 96 engineering professors at San Jose State University have left and most slots remain open (McDermott 1982, p. 87).

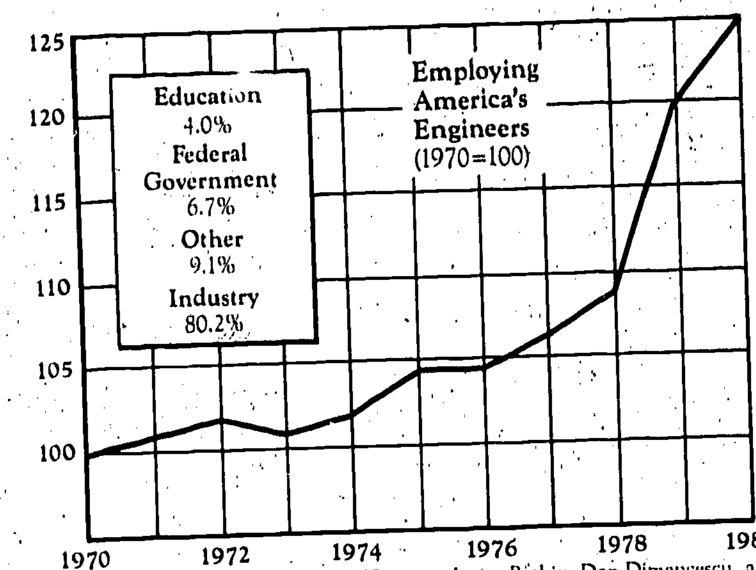

Fig. 7. Employing America's Engineers. [SOURCE: James Botkin, Dan Dimancescu, and Ray Stata, *Global Stakes: The Future of Technology in America* (Cambridge, Mass.: Ballinger, 1982), p. 55.]

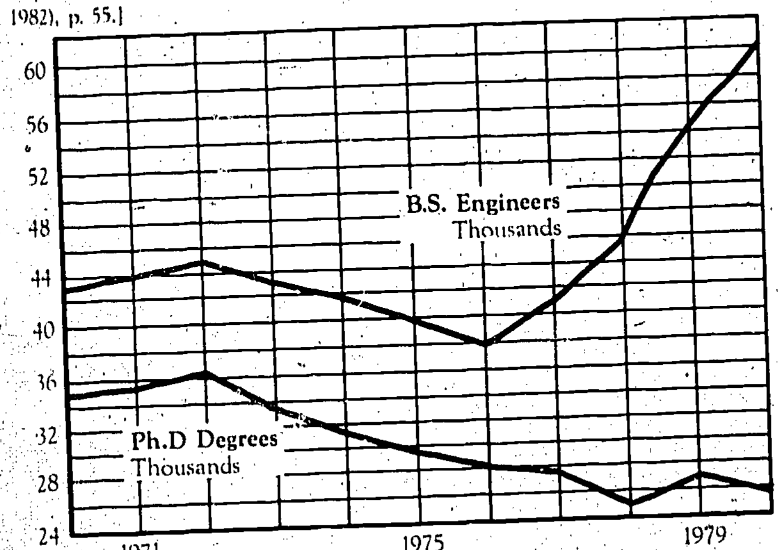

Fig. 8. Engineering Degrees: B.S. vs. Ph.D. [SOURCE: James Botkin, Dan Dimancescu, and Ray Stata, *Global Stakes: The Future of Technology in America* (Cambridge, Mass.: Ballinger, 1982), p. 57.]

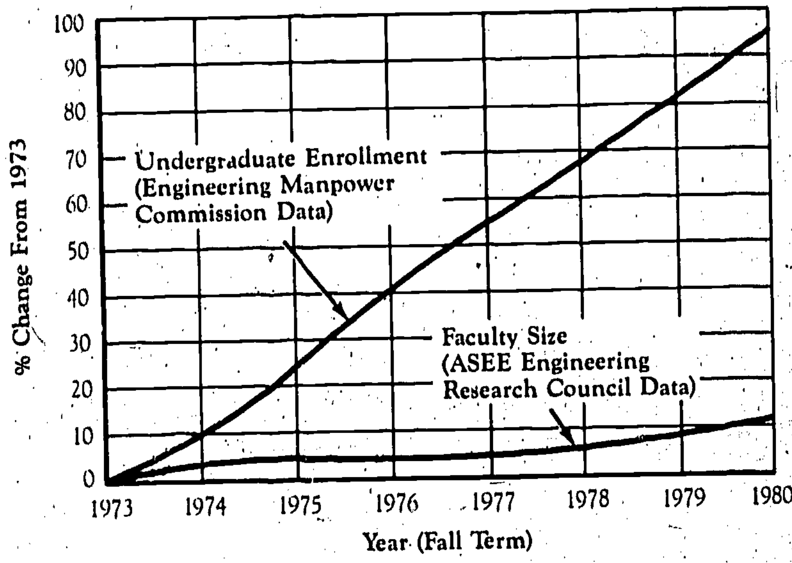

Fig. 9. Comparison of Growth in Engineering Undergraduate Enrollment and Number of Faculty, 1973-1980. [SOURCE: John Geils, "The Faculty Shortage: A Review of the 1981 AAES/ASEE Survey," *Engineering Education* 73 (November 1982):148.]

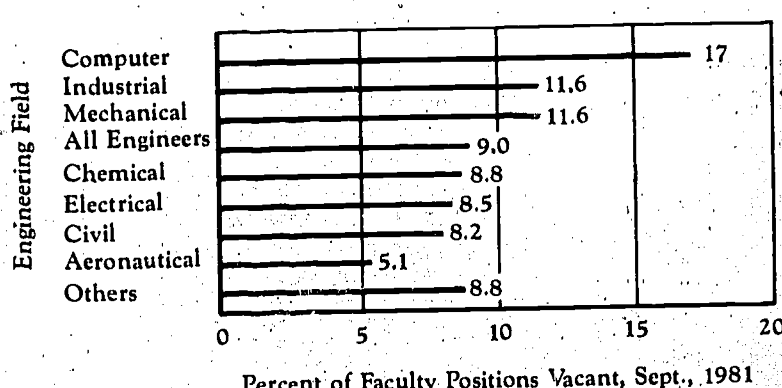

Fig. 10. Engineering Faculty Shortages. [SOURCE: Jeanne McDermott, "Technical Education: The Quiet Crisis," *High Technology* 2 (November/December 1982):88.]

Faculty shortages in computer science are particularly acute. During the period 1975-1979, there was a net increase of only 32 Ph.D. faculty, yet undergraduate enrollments approximately doubled. Moreover, in 1975 there were 60 computer-science departments granting Ph.D.'s in the U.S.; by 1980 there were 77 (Denning 1981, p. 342). In short, qualified faculty are being spread more thinly each year, and consequently, their teaching and administrative burdens become increasingly onerous.

The implications are clear: fewer doctorates mean fewer professors and, in turn, fewer engineers for the future. Having studied the faculty shortage in engineering colleges, John Geils asks, "Where do we find 1,050 new engineering Ph.D.'s who have the qualifications to be excellent teachers? The current annual Ph.D. crop is about 2,800, but 45 percent are foreign nationals. Of the remainder, a large fraction do not want to teach or are not qualified to teach. Only a few have the special motivation that is the hallmark of a really good teacher. Perhaps 350 real candidates for 1,050 positions—a crisis indeed" (1982, p. 152). Quite apart from its own requirements, education must triple its output of electrical and computer-science engineers each year for five years if it is to meet the needs of just the electronics industry.

The crisis involves far more than simply a faculty shortage. Its corollaries include reduced research and course offerings, increased teaching loads, and greater reliance on teaching assistants. One shortage produces another. While undergraduate and master's-degree enrollments are skyrocketing, fewer and fewer students are staying on at the doctoral level. As a result, departments are falling below the critical mass of Ph.D. students needed to function effectively. Without enough graduate students, there are not enough instructors to teach introductory courses. Rostered faculty must step in to teach these offerings, and this in turn decreases the time they can devote to research projects. Moreover, the lack of graduate students participating in faculty research projects can cause these efforts to wither. The cycle of decline continues: without the necessary level of research activity, federal and private research grants dry up, only increasing the exodus of faculty underway because of the lucrative salaries available in industry. As a result, research grants decline even further, making it ever more difficult to attract new faculty and potential doctoral students.

This cycle of decline suggests that factors other than salary contribute to the faculty shortage. Indeed, studies indicate that the eroding quality of academic life (such as increased teaching loads, fewer opportunities for self-directed research, and less freedom to choose and schedule one's own work) can be an even more significant factor than monetary issues (Eisenberg and Galanti 1981; 1982). Moreover, the faculty shortage predisposes us to see the crisis merely in terms of numbers. This tends to mask problems associated with the quality of faculty, their professional training, and their ability to place their academic work in the context of real-world problems. As foreign nationals account for a growing percentage of engineering faculty, it becomes important to stress not only knowledge and skills but also the continuity of traditions and values in the engineering professions. Although inadequate faculty compensation can precipitate a spiral of decline, larger salaries alone will not guarantee quality or even sufficient numbers. As industry and higher education begin to work together more closely, improving the quality of faculty and their academic life deserves to be placed high on their agenda.

Moreover, the faculty shortage problem cannot be divorced from graduate education and graduate-student support. What concerns David Saxon and others is that the federal government has completely misunderstood the importance of that support in its goal to increase innovation and basic research. "We have the notion," laments Saxon, "that we ought to charge graduate students more to go to the university rather than less, that somehow graduate students are a source of income rather than a group who need to be supported for the welfare of the nation."

Faculty shortages are hitting junior and community colleges particularly hard. The funding and support that community colleges receive vary widely from state to state. Even well-funded institutions, however, are having a difficult time coping with burgeoning enrollments in technically oriented courses. Elizabeth Useem reports many instances where an opening for a technical instructor attracts not even a single applicant. This results, says Useem, in an excessive reliance on part-time teachers. "To some extent they are essential in technical courses, being the only source of up-to-date instructors. But when you have a program with 10 full-time and 120 part-time people, you really lose control of quality."

There are no easy solutions to the faculty shortage faced by all types of institutions offering technology or engineering programs. The marketplace defines the parameters of the problem and, moreover, perpetuates it. John Slaughter emphasizes that solutions can only be arrived at through the cooperation of industry. "The payoffs to industry of supporting universities encompass more than new knowledge. An equally important payoff is the development of trained manpower. When there is collaboration between universities and industrial researchers on a project, with perhaps several industries participating, a dynamic sharing of knowledge takes place.... With this kind of activity, we need to move away from competition for personnel between industry and universities—or between different companies within one industry—and toward cooperation. We need to strengthen existing linkages and forge new ones."

Recognizing its need to protect the source of future employees and engineers, the business and industrial community has undertaken several noteworthy initiatives to help alleviate the faculty shortage. A number of corporations and trade associations have developed faculty grant programs. The AEA has established an educational foundation, one goal of which is to raise 300 faculty-development grants. The grants consist of $10,000 each and are added on to positions offered by colleges and universities, thereby turning a $19,000 position into a more attractive $29,000 position. The AEA is also supporting a program to develop 200 fellowship loans that will help support the graduate education of U.S. citizens who want to become teachers. The Exxon Educational Foundation will distribute $5 million for 100 teaching fellowships and $10 million for junior-faculty support at 66 schools. Over a decade ago, IBM initiated a faculty-loan program, whereby its professional employees teach in engineering schools while still on the company payroll. In 1983 IBM expanded its overall support to higher education to $35 million, a 50 percent increase over the previous year.

Even more encouraging, however, is the degree to which smaller companies are taking initiatives. A Santa Clara, California, company with only 19 employees recently committed a four-year fellowship to UCLA for the development of faculty. A small lighting company in Georgia has established a $250,000 education fund in honor of one of its deceased employees. While these initiatives make only a small dent in the overall problem, they are nonetheless highly significant examples of increased industry concern and support.

Financing and Utilizing Basic Research

Basic research is one of the fundamental responsibilities and contributions of higher education. Its own in-house research capability notwithstanding, industry looks to the university for the vast majority of basic research. About 75 percent of all basic research in the U.S. is performed by universities, the vast majority of which is funded by the federal government (Alic, Caldwell, and Miller 1982, p. 269). However, decreased federal funding of basic research has endangered at its source the flow of ideas into the innovation process. Although alliances between higher education and industry can complement government funding, they can in no way replace it.

James Botkin acknowledges that conventional wisdom in Washington and many state houses is that the private sector can somehow rescue higher education from its demise. "In principle," he says, "there is nothing wrong with this argument until you look at the size of the numbers. In 1980 the bill for higher education was $65 billion, with public institutions accounting for two-thirds of the total expenditure and private for one-third. Contributions from corporations amounted to about $700 million."

Support for university research and development serves as an even more important measure of university funding, for it relates closely to the actual needs of technology industries. In 1979, says Botkin, the funding for university R&D was about $5 billion, but less than 4 percent of this funding came from industry. Two-thirds of the R&D funds were provided by the federal government. (See figure 11.)

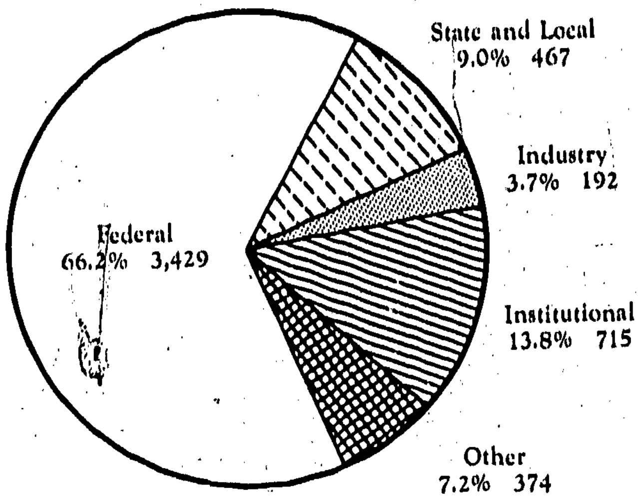

Fig. 11. Sources of Support for Academic R&D in Science & Engineering: FY 1979. [SOURCE: Jack Krakower, "Federal Support of R&D at Leading Research Universities," *NCHEMS Newsletter* 79 (Summer 1981):6.]

As important as industry support for higher education is, Botkin stresses that "it would be folly to think that industry's very best effort could compensate for even a 10 percent cut in federal government support of university R&D, let alone resolve the financial crisis in our technical universities. In short, there is no way for government, both state and federal, to get out of the business of higher education." Having said this, Botkin adds that "industry nonetheless has an important role to play. It is encouraging to see that industry is responding to the financial plight of higher education. The Council for Financial Aid to Education reported last year that contributions of America's largest corporations to colleges and universities are sharply on the rise despite the recession. In general, corporations are now beginning to see that support of higher education is not a charitable contribution, but rather a critical investment in resource development."

This distribution of responsibility for our nation's R&D effort on university campuses makes it clear why budget cutbacks at the National Science Foundation and budget increases at the Defense Department have created deep-felt concern. The authors of *Global Stakes* comment, "The double irony of the current budgets is that the greatly expanded defense R&D funds, mostly earmarked for industry, will consume scarce technical resources, while shrinking NSF funding, mostly earmarked for universities, will generate less new technical manpower" (Botkin, Dimancescu, and Stata 1982, p. 116).

The protests elicited by these budget cuts have been responsible for at least partial restoration of funding in certain areas. Nonetheless, the fiscal uncertainties encountered during the past several years have helped both industry and higher education recognize several fundamental propositions. "Universities need *steady* support," says John Slaughter, "rather than support in wide swings—swings that are welcome when they come your way, but which cannot really be counted on." "What universities might reasonably look for," adds Robert Rosenzweig, "is a kind of buffer from industry against the inevitable shifts of government policy. Government is fickle; its interests and focus change. What it thinks is important today is not necessarily what it is going to think is important tomorrow. Prudent university managers, therefore, ought to be looking for multiple patrons so that they can shift resources and buffer themselves against the sudden ups and downs of government interest. I think that business support can be an important element in this, though not the only element."

This effort to cultivate more diverse sources for the funding of basic research reflects one of our most important strengths: the diversity of our industry and our educational institutions. There has been a certain tendency these days to look to Japan as a model. But as David Saxon observes, it may very well be the wrong model "precisely because it lacks the diversity we ourselves need to take advantage of. We must find ways to experiment, to work within what I would like to call our particular and unique tradition."

Our educational and industrial diversity has contributed to the broad range of alliances between industry and higher education. Universities in particular are aggressively pursuing different kinds of partnerships with business and industry, having initiated the overwhelming majority of cooperative programs. However, the efforts of business and industry to respond to the plight of universities and their need for research funding have extended beyond specific joint research projects. The AEA, for example, has set an industry standard calling for each company to give up to 2 percent of its current R&D budget to the AEA Education Foundation. Given the size of the electronics industry, this proposal represents a significant attempt to deal with the crisis facing engineering departments and the research they conduct. Although lauding these efforts, Paul Bradley expresses some skepticism: "The Tax Act of 1935 made it possible for industries to contribute up to 5 percent of their total annual profits to education. Nobody has even come close to that. The avenues for providing support to higher education exist and have a long history, but we just haven't taken advantage of them."

Universities do encounter some risks when accepting industrial-research support. Colleges are particularly concerned that industrial participation and support will curtail academic freedom. In order to realize a profit from technological innovations, companies must protect proprietary information. This can hinder free inquiry and the open exchange of ideas, fundamental principles that make the university environment conducive to learning and research. Not only must individual academic freedom be safeguarded, the overall profile of university research must retain its diversity and balance. Corporations are themselves recognizing that undue secrecy can have a profoundly detrimental effect on the very environment to which they are turning for help. Current partnerships suggest that these problems could be solved if they are openly discussed and if both parties appreciate the common interests that draw them into collaboration.

A further concern is the possibility that applied research will drive out basic research. The commercial viability of recent developments in biotechnology may lead industry to expect quick results in the future. Lewis Thomas cautions, however, that "recombinant-DNA techniques could not have evolved without the 30-year background of research in virology and molecular genetics, almost all of it done without the faintest inkling that anything like recombinant DNA lay ahead" (1980b, p. 22). Both industry and government should invest in basic research, not for any immediate return but in order to keep an information bank filled and solvent so that in one or two decades knowledge will be available for new and unforeseen applications. "It is necessary to say these things," adds Lewis Thomas, "lest the people in charge of science policy become any more convinced than they already seem to be that useful and usable science can be ordered up whenever they like" (p. 22).

Perhaps of more immediate consequence are the effects that applied research might have on the instructional process, particularly among graduate students. This specter concerns Ray Orbach: "It is terribly important to me that universities not engage in activities that do not contribute to the instructional process. For this reason, some relationships with industry don't belong on a university campus. We receive a number of grants from drug companies, and I must say that some of them look rather suspicious to me as a university administrator. They tend to be more testing programs than real research grants." In a university setting, research is more than a disinterested pursuit of truth. It is also an important means of teaching students about the nature of inquiry and of their developing the skills and techniques they need to do quality research. Applied industrial research is appropriate in the university laboratory when it contributes to this process.

Direct industrial support of basic research in higher education is most obvious when in the form of financial contributions and highly publicized collaborative projects. However, alliances between corporations and campuses also contribute in less tangible ways.

Close cooperation among researchers, administrators, and organizations assists technology transfer and strengthens innovation in a way that money itself could never accomplish. Moreover, industrial support and participation has had a positive effect on the structure of university research. Engineering schools have traditionally been organized along rigid departmental lines, while the character of industrial research is more interdisciplinary. One of the major benefits of industrial participation in university research efforts is that this collaboration has required different academic departments to work more closely with one another. Stanford's Center for Integrated Systems is more than an excellent example of industrial participation in basic research; it has also contributed to cooperation within the university itself. although progress of this kind is not available as large financial contributions, it promises to pay large dividends in the future by making the innovation process more effective and efficient.

Upgrading Facilities and Equipment

Advances in basic science often depend on highly sophisticated equipment and modern facilities made possible by recent advances in technology. Without the telescope, Galileo could not have redefined the universe. Likewise, the dramatic scientific advances of our own day would have been impossible without the latest specialized equipment. Basic research, in short, is not a stand-alone enterprise.

Our nation, however, has not significantly reinvested in university facilities and equipment since the late 1960s. The consequence has been a grievous decline in physical plant, libraries, and laboratory and research equipment. University research often employs equipment that is one or two generations behind the state-of-the-art equipment used by industry. Instructional equipment is overtaxed and even more antiquated. This neglect has crippled both current research and the training of future teachers and researchers.

Most engineering programs are housed in facilities that are now about 30 years old. Federal support for university construction was running at a rate of $120 million per year in the mid-1960s but took a nosedive to $40 million by the end of that decade. Moreover, federal funding for scientific equipment in university laboratories has dropped 50 percent in the past 15 years. At many colleges, computers that should fill up a desk instead fill up a room.

The tale of decline and inadequate funding that we see writ large, as it were, in the physical plant of our colleges and universities is augmented by the day-to-day pressures and frustrations experienced by students and faculty alike. A computer-science degree, we soon discover, requires as much an education in patient endurance as it does an education in integrated circuits, programming logic, automata theory, and numerical analysis. Undergraduates often wait hours to use a computer terminal for sometimes just a few minutes, while graduate students and faculty vie for space in a computer's memory to carry out their research projects.

Antiquated equipment affects both research programs and undergraduate instruction. Faculty, graduate research assistants, and undergraduate students alike work with tools that have long left the industrial scene. Professors cannot give their students a sense of what the field is like today, and they themselves must frequently pursue their research interests on equipment that is sadly out of date. Jeanne McDermott's survey of the quiet crisis in technical education is most unsettling: "Equipment obsolescence plagues virtually all engineering schools. Researchers complain that outdated equipment is a prime factor in the professional flight to the private sector. Since 1970, laboratory-equipment costs have inflated 20 percent a year; maintenance, often demanding scarce and highly trained personnel, runs 7-8 percent per year of the original price. The useable lifespan of a cutting-edge instrument has dwindled to five years" (1982, p. 90). On the whole, says McDermott, instrumentation in academia is twice as old as that in industry. Upgrading university laboratories to industry standards could cost $1 billion to $4 billion.

Efforts to remedy the situation have been forthcoming from the federal government and the private sector. The National Science Foundation assists major research universities in the acquisition of instrumentation and computers. Likewise, private industry regularly makes charitable donations, often in the form of equipment. Data General, for example, donated equipment worth $3.5 million in 1981. IBM recently announced that it will give $40 million worth of computers to 20 colleges of engineering. It is quite evident, however, that far too little has been done. Corporations, for one, have yet to utilize tax deductions for donated equipment to the extent that they could. Moreover, the effectiveness of donated equipment depends on the degree to which a firm understands an educational institution's actual needs and can respond to them.

Reversing the deterioration in facilities and equipment entails not just money and in-kind donations from government and industry. It requires, more importantly, new and innovative ways of managing and utilizing both space and equipment. Business and industry not only can accommodate the immediate needs of higher education; they can also assist colleges and universities in exploring new methods of acquiring and utilizing facilities and equipment. Sharing space and expensive instrumentation through collaborative efforts in teaching and research is one of several possible alternatives. This represents, however, more of a short-term expediency than a long-range option. While these immediate needs cannot be deferred, higher education and industry must focus on more permanent solutions. Both with respect to instructional equipment and facilities for advanced research, the initiatives we are taking during the next several years will be crucial to the long-term survival of educational institutions.

The need for modern facilities extends, however, beyond computer terminals, research laboratories, and sophisticated instrumentation. To carry out their educational responsibilities, institutions must also invest heavily in libraries and other educational facilities that allow universities to function as intellectual focal points.

Maintaining the Health of Core Programs

Economic and technological forces exert pressure on colleges and universities to move in what are often conflicting and contradictory directions. Each day compromises have to be made and trade-offs considered. What takes priority: new research instruments for the engineering school or adequate support for the arts-and-humanities library? Updating the computing facilities or funding an innovative instructional program in the humanities? Increasing faculty salaries in computer science and engineering or providing long overdue cost-of-living increases for faculty campuswide? These difficult decisions must be made on almost a daily basis, and each poses a potential threat to the health of core programs in the university curriculum.

Commenting on these competing program requirements, David Saxon emphasizes that we need "more than laboratories and better salaries for our engineering faculty. At the moment there is a major threat to the vitality of our traditional liberal-arts programs because of the pressure to divert resources to more technical and scientific education. I think that would be a dreadful mistake for universities and for the nation. We need to emphasize the quality of support, and we need it across the board—not merely for science and technology but for core programs."

These pressures are felt by college administrators and state legislators alike. Lawmakers often control the purse strings of state educational institutions without being fully aware of conflicting pressures at play on the university campus or of the hidden implications of their decisions. Moreover, they are frequently under pressure to take politically expedient actions not always in the best long-term interests of higher education. A former faculty member at the University of Minnesota, Gordon Voss describes the same pitfalls that Saxon noted but from his current perspective as state legislator in Minnesota: "While legislators focus on fostering partnerships through new actions, they may forget their old responsibilities—adequate funding of the core of higher education.

The political pressure to fund innovation centers or designated programs is strong, as is pressure to cut spending. Lower core funding may be the result and, of course, create the weak link in the very partnerships we are trying to form."

Two arguments can be made for maintaining the health of core programs: the need to provide a broad education to university students, and the need to maintain balance in university programs and funding.

Addressing the first of these two propositions, David Saxon explains that "universities need students who want to be educated, not merely trained. Many students have an inappropriate idea of the challenge they are going to face in the future. They want to be trained for immediate jobs. However, I can't think of a better way to ensure obsolescence than to train students for particular employment. We are facing the consequences of that right now when we talk about a work force mismatched to our future needs. This current and mistaken emphasis on vocationalism at the expense of liberal education is something that we need to address seriously. We should help both engineering and humanities students understand that the best preparation for an unknowable future is broad education, not narrow training."

In one sense, the competing demands of vocationalism and liberal education have always been with us. It has never been sufficient for universities merely to train students. However, in an era of high technology and rapid change, the pressures exerted on students to make premature and often short-sighted career decisions necessitate that universities, more than ever, ensure them of a broad and liberal education. This is especially true in the field of engineering, because unlike medicine, law, and other professional programs, engineers can begin practicing with only a baccalaureate degree. As a result, professional training and general education compete for a student's time and attention during the formative undergraduate years.

Core programs require adequate resources, but maintaining a balance in university programs and university funding is not an easy task. Richard Van Horn describes some of the problems. "If you take a lot of work from industry, it tends to be in engineering or in science. Very few industrial sponsors would like to support a Renaissance historian. One consequence is that this distorts the kinds of resources that are available. In some senses, this is a more serious possibility with industrial support than it is with federal support. Some people are treated much better than others, and this leads to a very strange phenomenon. Those programs or departments that are most successful in getting sponsored research might reasonably be expected to be less successful in obtaining general university funds. In other words, because engineering has access to outside funds, one may decide to give more of your inside funds to, let us say, the history department." Reallocating internal funds can be an attractive prospect to beleaguered departments in the arts and humanities, but there can be other, less desirable consequences. A department that receives most of its support from outside sources may be inclined to be more responsive to requests from its funders than from the university.

Faculty salaries are also a thorny issue. Competition exists not merely between industry and university, but between different sections of the university community, who contend among each other for their share of often-dwindling resources. Greater investment in engineering faculty, notes David Saxon, can easily be misinterpreted as a statement that engineering is more important than the classics. The reality of the situation is that "if you want to be excellent in engineering, as excellent as you want to be in the classics, costs are different. The pool of available faculty is different, and hence recruitment policies within the university must be different. You have to take these into account if excellence is your goal."

Should engineering schools and computer-science departments be offered a smaller portion of the university financial pie, given the fact that they receive substantial outside funding? To what degree should the marketplace control university salaries, thereby creating tremendous disparities in compensation between engineering and liberal-arts faculty? These questions are troublesome precisely because they concern not merely budgetary items but, at a more fundamental level, the character of instructional programs, research directions, and educational mission. Each particular campus has, of course, its own priorities and its own internal dynamics, both philosophical and political. A workable solution must reflect these specific circumstances. In this sense, campus debate is an intramural affair. Nonetheless, when industry and higher education forge alliances, they should develop greater awareness of the campuswide effect that their partnership might have and the tensions it could create.

Developing New Patterns of Education

As we noted at the outset, higher education cannot present its needs to business and industry as one would a shopping list. Adequately meeting these needs entails a significant degree of internal reevaluation and self-reflection. This is particularly true when we speak of developing new patterns of education. Some aspects of partnership do require that each party fulfill Voltaire's injunction to cultivate its own garden.

Changes in the workplace, the emergence of high technology, and a greater desire to develop human resources have expanded the range of educational responsibility for both industry and higher education. Just as education has made its way onto the corporate agenda, so too have continuing education and worker training affected the overall mission of educational institutions. While it is true that this trend has been underway for several decades, the advent of high technology, the retrenchment of many of our educational institutions, and the economic situation facing business and industry all combine to give this topic fresh urgency. We can no longer dismiss the signs that call for changing traditional patterns of education. Four years of college is no longer sufficient for a 40-year career. In an age where the half-life of an electrical engineer is five years or less, the university, in its own self-interest, must expand its horizon beyond formal "higher" or "postsecondary" education as traditionally understood. By definition this demands a close working relationship with business and industry.

Efforts in this direction, however, have been at times ineffectual, half-hearted, and rather awkward. Elizabeth Useem reports that some company officials see institutions of higher learning as "bumbling in their efforts to approach industry for help" (1982, p. 61). One executive interviewed by Useem, for example, cited the failure of schools to write high quality, focused requests for company support. Others commented on what they felt was the narrow arrogance of some schools who wanted corporate money but no advice on curriculum development. They argued that many schools have failed to form viable employer advisory boards for fledgling programs. The training director of one large firm commented that those schools that were not arrogant often veered to the other extreme of 'pandering' to a company's short-term needs. Others pointed out that no university has developed a systematic sequence of retraining programs to prevent experienced engineers from becoming obsolete.

Educational institutions are, however, making substantial progress in responding to these numerous opportunities. As colleges reevaluate educational patterns and programs, they need to take into account specific community needs as well as the specific contributions they are in a position to make. Nonetheless, we can mention four general areas that require new educational patterns and perspectives.

The first involves those individuals that colleges consider as prospective students. In recent years, they have grown accustomed to looking beyond the 18-to-22-year-old age group and recognizing in the adult working population a large, perhaps inexhaustible pool of potential learners. Nonetheless, they have yet to fully recognize that this change in student population requires forging close alliances with business and industry.

A second area involves the scheduling of programs and courses. As universities come to see education as a lifelong process and not necessarily as a discrete four-year period, they will find it necessary to incorporate short-term, specialized courses in their academic calendars and to use new delivery mechanisms. Industry, they soon discover, operates neither on the semester nor the quarter system, nor is it convenient for employees to attend classes from 9 to 5. Broadening the scope of educational patterns through alliances with business and industry requires, then, a willingness to consider schedules and course options that might have appeared unconventional some years back.

A third topic has to do with the physical location of the educational enterprise. As new patterns of education evolve, the company conference room and the industrial laboratory will join the college campus as sites for teaching and research. Community colleges have been willing to leave the familiar campus environment and offer in-house courses at company locations. Four-year institutions, on the other hand, are less inclined to forego ivy-covered walls; as a rule, most of them expect students to come to them

A fourth area concerns the intent of educational programs, an important question that subsumes the three topics we have discussed thus far. What is the proper balance between liberal general education and programs designed to meet a specific need? For community and junior colleges, the question often presents itself in terms of the balance between lifelong continuing education and the pragmatic retraining needs of business and industry. For the major research university, the issue is likely to take the form of the degree to which directed or applied research is consistent with its general commitment to basic research. The proper balance is one that each educational institution must find for itself.

The four areas we have touched upon are not radically new. Partnerships between higher education and industry require, however, that they be viewed in a new light and with greater urgency.

Adapting Organizational Structures

Colleges and universities are discovering that if they wish to foster and take advantage of partnerships with the business community, they must alter some organizational structures and practices.

As Colorado Governor Richard Lamm observes, "The management question posed by high technology is how to adapt traditionally slow-moving institutions to rapid change. Neither education nor industry is currently in a maintenance mode, with a stable body of knowledge and management practices to pass on to the next generation. That used to be the case. We are now in a catch-up mode, running after a body of technological knowledge that itself goes through several generations in one lifetime. Steel workers haven't admitted, higher education hasn't admitted, politicians haven't admitted that yesterday's solutions are no longer appropriate to tomorrow." Like many of the needs we have discussed above, this one entails a willingness on the part of higher education to accommodate new circumstances. Forging alliances between individual researchers or administrators is itself not difficult; rather, the most frequent obstacles tend to be bureaucratic structures unresponsive to the new needs presented by these alliances.

An immediate obstacle can be the difference by which educational and industrial institutions cope with the change. The rapid tempo of industry often contrasts with the slower pace of educational institutions. Hiring policies, for example, differ markedly. Useem recalls one company official saying to her, "When we hire someone we don't even write letters. We use the telephone because we want that person to be here on Monday." In academia it can take months, often a year, to hire new faculty. Given the considerable amount of time required to launch a new program, it is understandable why industry can sometimes become impatient with colleges and universities. Industry is often perceived as moving at 60 m.p.h., and the educational sector at 15 m.p.h.

Existing ties between higher education and industry frequently take the form of individual contacts and personal acquaintances. Consequently, the lack of established links on the organizational level becomes an obstacle when both parties seek to formalize their alliances. Business leaders complain of a bureaucratic maze that slows down the adoption of new programs. Numerous individuals must be contacted and approval must be sought from many different offices, boards, and groups. Oftentimes they have little communication with each other on a regular basis.

Many universities have not been equipped to handle emerging partnerships with business and industry. Organizational structures dealing with these alliances frequently have been ad hoc. Until just recently, "it was a rare qualification," notes George Baughman somewhat tongue-in-cheek, "for a university administrator to know where the Chamber of Commerce building was, to have seen live businessmen, not to mention having a passing acquaintance with Rotary luncheons." In the past several years the situation has improved. Nevertheless, nurturing outside contacts can still be difficult. In fact, it can be no less arduous for a university administrator to establish and continue an effective internal dialogue between faculty, department chairs, deans, central administration, finance, and the office of contracts and grants. In the best of all possible worlds, these efforts may be likened to an intricate ballet. In less sanguine moments, one may be tempted to view the endeavor as a frustrating and endless game of "bumper cars."

As colleges and universities become more accustomed to dealing with the business community, lines of communication are opening up. Access is not quite the problem that it used to be. Nonetheless, a major obstacle to more fruitful alliances with business and industry remains the outmoded structure of university administrations. The patent office, for example, is often tucked away in some remote corner of the legal office. It could operate much more effectively if it were in direct and regular communication with those initiating and working on partnerships. The degree to which higher education and industry have been insulated from one another in the past is perhaps most evident now that we confront the organizational structures that contributed to that insulation. Of the six needs we have mentioned, modifying an organizational structure to accommodate and encourage further partnership is one that can be met most readily. In doing so, colleges and universities greatly improve the prospect that cooperative efforts with business and industry can make tangible progress in the other five areas.

The Special Role of Community Colleges

Community and junior colleges play an important special role in alliances with business and industry. They generally offer greater access to the community, and in turn the community has a greater voice in their educational programs and services. The responsiveness of community colleges to partnerships with the business community is not merely a given; these ties have been carefully and energetically nurtured during the past two decades.

Recalling the recent history of community colleges, we note that the number of two-year institutions exploded from 663 in 1960 to 1,234 in 1980. Enrollments during this same period grew from 660,236 to 4,825,931. In 1965, 14 percent of the 1.3 million students enrolled in community colleges were in occupational education programs. In the 1979-80 academic year, 63 percent of the 4.3 million students in the colleges were in occupational programs (Jackman and Mahoney 1982, p. 8).

In these figures, we can trace the evolution of two-year institutions from predominantly transfer colleges in their early history to comprehensive colleges that now offer a variety of educational and occupational opportunities. In our uncertain economy the special capacities of community colleges are achieving recognition, and their occupational component predominance. Two-year institutions currently offer nearly 1,500 different occupational programs, including degree, certificate, diploma, and noncredit opportunities. A special feature of community and junior colleges is their intimate ties to local business. These ties are often nurtured by the institution's administrative structure. Boards of trustees, for example, are usually drawn from the local business community. This arrangement provides the private sector a direct hand in shaping educational policy at the institution and gives them insight into the services that the college can provide.

In spite of impressive links with community and business leaders, many two-year colleges are recognizing the degree to which they have structured themselves along the lines of major univerries. Commenting on this problem, Nolen Ellison observes that huge educational edifices have been constructed across the countryside, and yet many important educational needs are not being met. "What we've left out," he concludes, "are the apprenticeship-related training programs responsive to industry needs." Commenting on his own institution, Cuyahoga Community College, he notes, "We built a little miniuniversity. We've done a lot of things that address classical and traditional undergraduate education. What we didn't build was the piece that is job specific, and that is the focus of our current efforts."

The history of each institution, of course, varies greatly, as does its size, the nature of its educational programs, and the amount and source of its support. Nonetheless, the efforts of Cuyahoga Community College to strengthen its ties with business and industry are representative of nearly all two-year institutions. The efforts of these institutions are laudable, but the support they are receiving is mixed and often quite insufficient. Although industry generally regards community colleges as the most flexible and responsive sector in the higher-education system, many companies don't actually give them a lot of money and support.

The response of community colleges and the support they receive vary greatly from state to state. In some areas, such as California, community colleges have the resources and the inclination to respond to changes in the work force. In other states, such as Massachusetts, they are so poorly funded that survival itself becomes a shoestring effort. Useem describes one community college in Boston that has never received a single penny for capital equipment. Until recently their building was a condemned nursing home outfitted with innumerable bathrooms but hardly one small lab. Many community colleges are training beyond their capacities. Students are lined up at terminals; equipment, facilities, and faculty are frequently inadequate to serve what is an obvious and pressing need. However, when provided adequate support, community colleges are given high marks by industry for the quality of their programs and their responsiveness in meeting local needs.

As two-year institutions strive to meet the needs of their communities, they must confront two issues: the balance between short-term training programs and long-term continuing education, and the effect of high technology (and the vocational needs that accompany it) on their overall educational mission. "The pragmatic issue for many businesses and industries," says Ellison, "is how we can train people in the shortest period of time possible so that they can work in our firms. At the other extreme to this short-term pragmatic problem is the lifelong venture of educating the whole person. I think we can do both, we're attempting to do both, to bridge the gap between the short term and the long term."

Many college administrators nonetheless express concern about incorporating immediate needs into an institution's overall and long-term educational philosophy. These administrators, observes Useem, are in a bind. "Student demand for technology and engineering programs is there and they must respond to it. A rough consensus has developed among administrators to expand these programs somewhat, but not to such a degree that it distorts the whole mission of the college or university or drastically takes away from the liberal arts. As a consequence, there is a modest reallocation of resources and facilities. Administrators are still very burned by what happened in the 1970s when engineering enrollments plummeted. As a result, they are petrified about expanding these expensive programs and then possibly finding that the nature of the demand was cyclical." While nearly all community colleges recognize the importance of high technology to their curriculum, they are nonetheless hesitant to make drastic changes in their educational mission. Said one administrator to Useem, "I'm always fighting attempts to make this a technical institute. We want to leave some room for the liberal arts."

In order to minimize the conflicting demands of short-term and long-term education and the vagaries of a fluctuating economy, and protect the integrity of an institution's educational mission, local institutions must operate at the community level. Ellison stresses that if cooperative models are to be successfully applied, they must be highly localized. "Individual institutions will achieve greater success in launching partnerships as they tailor their efforts carefully to the unique needs and circumstances of their particular community." This tailoring task requires a strategic approach to institutional planning and program development. It differs from more traditional planning in its explicit and detailed attention to the external environment and by its focus on effective communication and innovation, rather than on management control and efficiency. Community colleges can be especially effective partners for industry precisely because they operate at the local level. They are willing to respond to community needs and have the flexibility to tailor programs to a changing environment.

The Needs and Interests of Industry

GROWING FOREIGN competition, the transition from sunset to sunrise industries, and the increased need for skilled professionals are but some of the reasons why the business community is seeking collaboration with the university campus. Philanthropic motives may account for some industrial aid to higher education. However, business leaders are beginning to realize that support of higher education is, in the words of Edward E. David, Jr., "consistent with a commercial 'mission'" (1982, p. 42).

Recent and very rapid developments in biotechnology have convinced many business leaders that participation in university research could well be crucial to their performance in the marketplace. When seemingly arcane research in a pure science became a marketable product almost overnight, industry was embarrassed to find itself as little more than an interested spectator. Industry executives are realizing that such revolutions can occur in any number of fields and that to take full advantage of new university research they must work now to establish viable partnerships. Moreover, the volatile high-tech business environment has persuaded corporations that higher education is a strategic, long-term resource. Without cooperation from college campuses they cannot hope to meet their own pressing needs, in particular:

1. Human resource needs
2. New windows on research
3. A renaissance in innovation
4. Adapting organizational structures and perspectives

Human Resource Needs

Our earlier discussion of the faculty shortage facing American engineering schools has already introduced some of the human-resource problems encountered by business and industry. We can now discuss this need in greater detail from industry's perspective.

A shortage in skilled professionals and highly trained workers has slowed our industrial progress and dulled our competitive edge in world markets. The percentage of scientists and engineers in the American labor force has been declining since 1965, while it has doubled in Japan and Germany. Reduced federal support for higher education and the severity of the engineering shortage are such that colleges and universities are not in a position to remedy the situation by themselves. To an increasing extent, industry is recognizing the problem as its own, and is now cooperating with educational institutions to arrive at solutions.

Although the recent recession has temporarily masked the problem, we are in fact running out of engineers. They are not being trained quickly enough to meet the growth needs of the high-technology industry. James Botkin describes the situation as it relates to the electrical-engineering work force. Electrical engineers account for 25 to 30 percent of all engineering graduates today and are the ones in greatest demand by the electronics and computer industry. The present size of the work force of industrial electrical engineers is about 200,000 (see figure 12). Although new graduates will annually increase the electrical engineering work force by about 8 percent through 1985, each year about 6 percent will either retire or leave for jobs in management, sales, or marketing that require technical expertise. "The result," says Botkin, "is a net growth in the engineering work force of about 1.7 percent per year."

On the demand side of the equation (see figure 13), Botkin informs us that from 1959 to 1979, employment in the electronics industry grew by 3.4 percent. The government projects annual growth in the 80s to be 2.6 percent. "But considering the buildup of military spending, which is very engineering-intensive, and the pervasiveness of electronics in nontraditional applications like video games, personal computers, and automobile engine controls," Botkin does not find it "hard to imagine that growth in the last half of the 80s will be more like the 60s, when it averaged 5 percent. But for this to occur will require the number of engineering

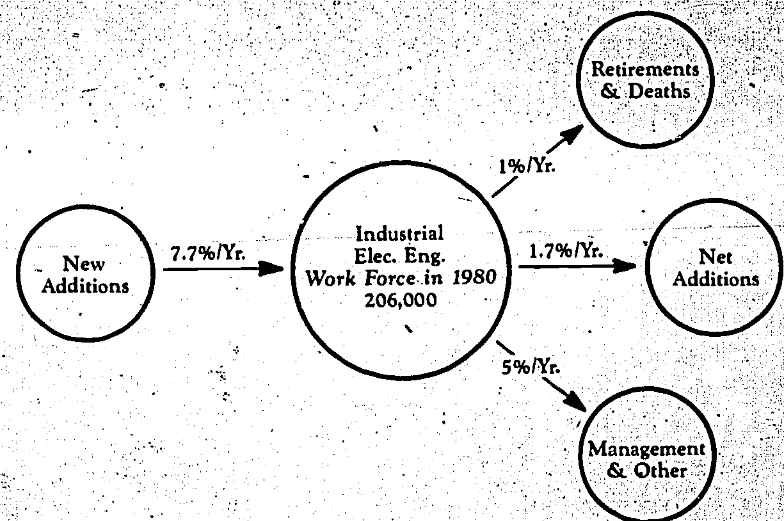

Fig. 12. Net Growth of Electrical Engineering Work Force Through 1985. [SOURCE: James W. Botkin, "America and the 20th Century: New Industries, New Values, New Challenges," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.]

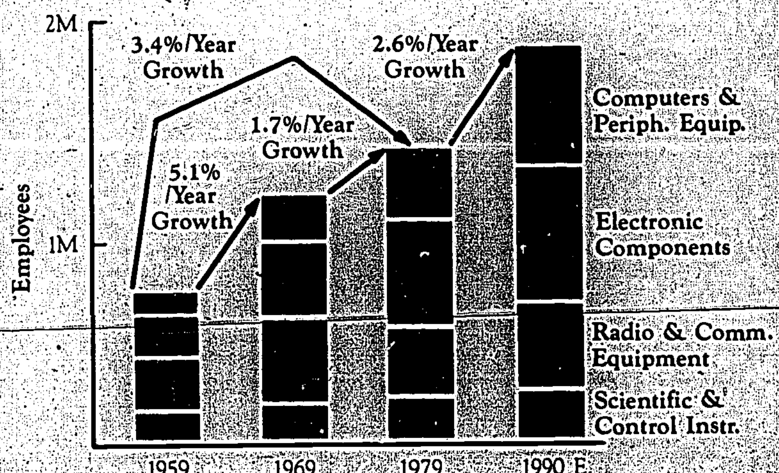

Fig. 13. Employee Growth in the Electronics Industry. [SOURCE: James W. Botkin, "America and the 20th Century: New Industries, New Values, New Challenges," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.]

graduates to double by the end of the decade."

"The prospects for increasing engineering output," warns Botkin, "are not very promising." This is not due to lack of interest from qualified students, but because the capacity of our engineering schools is limited. Undergraduate enrollments in engineering schools have soared, but without a commensurate increase in faculty and laboratory facilities. Thus, many schools are capping engineering enrollments and turning away qualified students while they concentrate on the quality of their engineering programs.

What makes this bad situation worse is that other countries are aggressively competing for a larger share of the high-tech market. The growth and stability of our high-tech industries will be paced by the availability of people with the right education and training. Botkin notes that only 6 percent of our nearly one million college graduates major in engineering, as compared to 21 percent for Japan and 37 percent for West Germany (see table 4). He can only draw the inevitable conclusion: "If we do not have the people ready, Japan and Europe will."

Table 4

Percentage of Engineering Graduates to Total Bachelor's Degrees—1979

Country	Total Graduates	Engineering Degrees	% Engr. Degrees
West Germany	60,436	22,400	37.1
Japan	315,122	65,422	20.7
United States	949,000	54,600	5.8

SOURCE: James W. Botkin, "America and the 20th Century: New Industries, New Values, New Challenges," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.

The unmet need for more skilled professionals translates into intense competition for those that are available. This creates a high degree of instability in industry and, in turn, makes for an unstable situation on the university campus. In 1981, our institutions of higher education generated only one-quarter of the undergraduate computer majors sought by industry, only one-tenth of the master's graduates required, and one-quarter of the Ph.D.'s needed (Useem 1981, p. 19). As a consequence, the demand is intense, particularly in areas with a substantial number of high-technology industries. The annual personnel turnover in electronics firms averages 35 percent and runs as high as 60 percent in small companies. The fast tempo of the "Silicon Shuffle" only exacerbates the situation on campus.

When it attracts faculty from engineering schools into their own ranks, industry only succeeds in undermining the very institutions to which they must turn for help. The shortages are such that companies find themselves eating the "seed corn" that ought to produce the next generation of engineers. Faced with the age-old problem of robbing Peter to pay Paul, industry now realizes that it too will lose in the long run if it does nothing to correct this situation.

To meet their own work-force requirements, corporations must cooperate with colleges and universities if they are to train new skilled workers and serve the experienced worker as a midlife student. But as Nolen Ellison remarks, the most striking characteristic of our training and retraining effort is that it is anything but systematic. "An incredible hodge-podge of legislation, policies, programs, and administrative mechanisms comprise the human-resource development area. Not only is there no national strategy, even basic coordination is a rare enough phenomenon. At the local level, we almost always find a bewildering array of 'mini' systems engaged in employment and training activities, typically with little coordination or even communication, much less comprehensive planning."

Moreover, manpower needs often fluctuate wildly. This can often strain university-industry partnerships devoted to human-resource development. Ellison describes, for example, a highly innovative program undertaken by Cuyahoga Community College—a program that nonetheless could not escape the difficulties created by a fluctuating job market: "We were operating a training program for screw-machine operators. They are a critical part of the American industrial complex, but the average age of workers in this field is in the high 50s. Three years ago, firms, unions, and CETA sponsors in our area came to us and said, 'Will you help us develop a program? We need people but we can't find them.' As a result, we scurried about, got all of the equipment out of mothballs, and hired retired union people to be the instructors. It was a beautiful example of how business, industry, unions, and education can all cooperate together. When we started producing trainees out of that program, 90 percent were placed in the first year without any difficulty at all. But now we are about to close the program down. No one can be placed, at least not in the immediate, short-term future. But five years from now we are again not going to have enough screw-machine operators."

Ellison's experience illustrates the difficulties of integrating the long-term nature of human-resource development programs in the immediate, short-term ups and downs of business cycles. Commenting that one "can't keep people waiting on the shelf until they are needed, or train them without the prospect of a job," Ellison laments that many programs are caught in "a conflict between long-term needs, almost predictable barring a complete collapse, and short-term cycles that result in the surplus of available labor one year and a shortage the next. Unless we have a sufficient degree of critical talent, a kind of 'talent bank' concept for the long term, industry's manpower needs aren't going to be met."

Strategic planning on the local level brings to light not only the disarray of training programs but also their extensive overlap, even duplication. This leads James Alleman to reflect on the future of training programs at Mountain Bell in light of AT&T's divestiture: "Traditionally we never really relied on the academic community to provide us skilled and educated workers. We paid taxes like everybody else. Because there were very few other companies who needed a telephone repairman, or a central office technician, or an operator, we developed a total training and educational technology program for our own internal use. With divestiture and new competition in the telecommunications market, perhaps there is no reason to keep all of this internal. Maybe there are some real benefits in sharing some of that technology back and forth with the educational world."

Duplication of this sort exists in almost any industry, and indeed often within one community. As corporations seek to become cost-effective, shared human-resource development provides both a logical and practical alternative. Cooperation can take the form either of general training courses offered by a college or university, or of courses specifically designed for a particular company and offered on-site.

When speaking of partnerships in training and human-resource development, we should remind ourselves that teaching people skills is not enough; we must teach them how to utilize those skills. "What we need," says Alleman, "is not only a better way to acquire the skills and knowledge necessary to perform effectively in tomorrow's marketplace. We also need educated individuals who are capable of applying that knowledge in the real world. Most people are so concerned about whether they are going to get the boss's approval that they are unable to strike out on their own. We don't need workers who utilize their education merely to support and perpetuate the bureaucracy, who just sit wringing their hands, saying, 'If only the other department would get cleaned up, if only they'd send me the right kind of people, if only I had more funding.' These individuals may be well educated and highly skilled, but they are not going to be effective in our working environment. The mutual challenge faced by higher education and industry is to concentrate not only on the acquisition of skills, but also on the ability to apply them."

If industry is to meet the challenges of training and retraining its workers, it will need to assist higher education in restructuring curricula and updating educational perspectives. Alliances between higher education and industry can provide a means for practicing engineers and other skilled professionals to renew themselves through a variety of continuing programs—some on campus, some in-house, and some in cooperation with other high-technology firms. "We are all aware," says Monte Throdahl, "that unless an engineer can upgrade his skills, he is over the hill after he is 35. But a good engineer is forever in demand. We can't spare him for a year's sabbatical. Pretty soon he turns 40, and then he is too old; he can't be 'retreaded,' or so the conventional wisdom goes."

Industry can assist higher education in this effort by identifying weaknesses that arise from either arbitrary or outmoded divisions of learning. The identity of an academic discipline can be important, especially to those who have a vested interest in the affairs of a department or in some section of its scholarly turf. But divisions of this sort often contribute to an outmoded curriculum and a fragmented research effort. "With a more interdisciplinary approach," says Throdahl, "we can assure the continuing excitement that goes with doing things in a leadership role. We need to foster this leadership by encouraging the university to become a part of a revitalized, national engineering community, rather than allowing it to remain on the periphery of an engineering community that was suitable for yesterday."

New Windows on Research

Just as higher education requires additional research support, industry needs better access to university research. This has become necessary because traditional forms of dissemination [illegible] no longer keep up with the speed at which an information society churns out research results. Moreover, the situation has been exacerbated by the isolation of industry and higher education in years past. "The lack of an active cooperative research relationship between universities and industry makes the dissemination of university-generated research results and their incorporation into product development random and uncertain" (National Commission on Research 1980, p. 11). Because the publication of research results has grown enormously, it has become difficult, even impossible, for industry to identify important findings, relate them to actual, needs, and capitalize on their economic potential.

Most of us will no doubt nod our heads in polite approval, fancying that we understand the full extent of the problem. But John Naisbitt warns us that for the first time our economy is based on "a key resource that is not only renewable, but self-generating. Running out of it is not a problem, but drowning in it is" (1982, p. 24). The figures cannot but shock even those who are substantially aware of the problem:

- Between 6,000 and 7,000 scientific articles are written each day.
- Scientific and technical information now increases 13 percent per year, which means it doubles every 5.5 years.
- But the rate will soon jump to perhaps 40 percent per year because of new, more powerful information systems and an increasing population of scientists. That means that data will double every twenty months.
- By 1985 the volume of information will be somewhere between four and seven times what it was only a few years earlier. [P. 24]

We are faced, as it were, with the high-tech equivalent of the Great Flood. However, industry's capacity to tread water is not unlimited. Concerned with effective dissemination of scholarly research results, many educational institutions have entered the commercial world of publishing. Oxford University is a notable example. This is, however, no longer sufficient. Increased social and economic responsibilities and the rapid pace of scientific and technological change require today's academy to form more direct and efficient ties with social and economic institutions.

Companies value the university connection precisely because it gives them new perspectives on new science and technology. Speaking of their importance to the Monsanto Company, Monte Throdahl cites recent developments in biotechnology. "For many years, most researchers in the physical sciences worked in the industrial sector, and the minority has been in the academic sector. In biology, the situation is reversed, almost to the same percentages. We in high-technology industries are sallying forth into this world of biology with some fear. As a consequence we recognize how terribly important windows are. I can say unequivocally that without the Harvard arrangement that we've had for these several years, we would never have seen or understood many things. University researchers provided us with new windows."

Difficulties in understanding and utilizing the information that flows from university research is only part of the problem. Ray Orbach also notes the lack of feedback from industry to the university: "Problems encountered by industry in the innovation process often remain unknown to university researchers. These problems can be quite exciting, and when solutions are developed, rather rewarding." As Christine Bullen emphasizes, "The primary way to ensure the relevance of our research at the Center for Information Systems Research at MIT is to keep very close contact with industry." Opportunities for exciting research can emerge from questions pondered in industrial research and development, and they can be missed simply because of lack of communication. Cooperation between university and industry researchers benefit both, enriching the university intellectual environment as well as contributing to the innovation process.

How can we best open these windows? Mechanisms for cooperation between industry and higher education vary, of course, and they must be specific to the needs of both parties. In the next chapter, we will outline the wide spectrum of possible partnerships. Nonetheless, we might mention at this point two basic configurations that alliances might take. In a research affiliate program, a number of corporations help support a university program and in return receive access to information. Research agreements provide a second and more intimate kind of cooperation. This relationship entails the active participation of business and industry in a university research program.

Windows, however, permit light to pass in two directions. This is no less true of research results and proprietary information. The more intimate the cooperation, the more transparent the pane of glass. There is, consequently, a greater possibility that proprietary information may be lost. The trade-off between what industry sees through a window and what others see through it must be evaluated on a case-by-case basis. However, the great variety of possible relationships with higher education is such that a partnership appropriate to both parties can usually be established. New windows, it might be said, are never lacking if one is willing to tear down portions of a wall.

Opening these windows on research and looking through them should by no means be construed as a passive or self-serving enterprise on the part of industry. It is not, so to speak, a form of technological voyeurism. At the same time that windows benefit industry, they also ensure universities of support for their research programs.

A Renaissance in Innovation

The decline of our competitive position in world markets has prompted many to question the speed and efficiency with which we are able to translate basic research into useful products. While few would deny our preeminence in basic research, signs are abundant that we need to stimulate innovation and technology transfer. "The trick," suggests Ray Orbach, "is to bring the richness and diversity of thought that take place at the basic-research level into the development and production phases."

Innovation is a subtle and oftentimes fickle process whose course cannot adequately be understood if we think only in terms of final products and new technologies. Moreover, innovation is not the province of any one sector of the research community; it cannot be found on the university campus any more than it can be found in industrial labs or corporate board rooms. In attempting to increase the yield of innovation and smooth the process of technology transfer, we would do well to bear in mind that a certain degree of randomness is inherent in the process. Bent as we are on nurturing innovation, we should also be aware of suffocating it through our ignorance of its many subtleties. "There are few who would argue," says Throdahl, "that the *results* of socially responsible innovation are not wanted. We would dearly love to have them. But arguments as to how innovation might be fostered usually fail to recognize its fragile nature and the dominant role that uncertainty plays in its process."

Progress has been the hallmark of our culture, and innovation a critical ingredient in that process. But Monte Throdahl points out the irony that we never seem to find a good time to pursue innovation. "When the economy is up, we are too busy to worry about the future. Don't change a good thing, we say. Likewise, when the economy is down, we are again too busy to worry about the future. There may be no future, we mutter in reply. When the economy is in a major transition—and that's what is happening right now—most people wish it weren't changing. They struggle to hang on to what has made them most comfortable. These, then, are some of the emotional experiences we have with innovation. It causes change and, in turn, causes us to be very uncomfortable about relinquishing the ideas that we've grown up with. Management tends to budget innovation projects on a 'donation basis,' instead of what I would like to think of as an 'opportunity basis.' And then that same management wonders at a later date why they don't have more innovation. Moreover, government sets regulations to prevent harm, and justifiably so. But sometimes these rules are handled inconsistently or become exceedingly complex. And then later, many in Congress and in our citizenry wonder why we don't have more innovations."

Collaborative efforts between industries and universities will help immeasurably to reduce the randomness of bringing the fruits of innovation to the public, thereby improving our current low yield. "To do this," says Throdahl, "we must learn how to bridge disciplines (often fiefdoms) and thereby bring wholly new and rational approaches to such critical problems as the environment, energy, information, and biotechnology." Moreover, we must place partnerships in a broad and innovative context. "Alliances," adds Throdahl, "can and should do more than undertake specific research projects. They offer a way of pursuing systematic experiments in cooperative thinking about new ways of dealing with social issues and problems. For example, it would please me greatly if corporations and campuses could collaborate on that whole problem of scientific dispute resolution called 'risk assessment.' Any of you who have been involved with this know it is a mixture of mathematics and values—and a very tough kind of equation to work out. Industry can find in higher education a resource to help it recognize emerging societal and technical discontinuities, such as our transition to an information economy. We must develop a willingness to anticipate change and prepare for its consequences. Without these efforts in cooperative thinking, a renaissance in innovation hasn't much of a chance."

By its very nature, the innovation process leads us to question the proper relationship between basic and applied research. Richard Van Horn observes that faculty often question the intellectual worth of sponsored, applied research. For Van Horn, the distinction between applied and basic research misses the mark: "In most cases we have found that we can always take the basic project and find something intellectually stimulating that is of genuine interest to both the corporation and the university." Van Horn's comment reflects the growing consensus among educators that a university's concern for the intellectual and educational value of their work need not rule out applied research.

The traditional division between basic and applied research, says Harvard president Derek Bok, has unfortunate consequences: "It is fitting that professors should proclaim the values of basic research and understandable that they should do so zealously to resist pressures to channel their work toward excessively practical ends. But it would be unfortunate if academic scientists pressed their case so far as to depreciate the value of applied research or to dismiss any effort to consider the potential applications of scientific work. Such attitudes could lead investigators to neglect important problems of genuine intellectual challenge" (1982, p. 152).

As Throdahl emphasizes, preventing the flowering of innovation represents a substantial risk. "Innovation will be squeezed when industry and academia effectively retain the status quo—in outmoded organizations, policies, and procedures. Given that high technology matures very quickly, innovation will also be slowed when mature industries do not look for new windows from academia—windows for new discoveries, new explanations, new ways to organize intellectual disciplines. Moreover, innovation will stop under conditions where leaders see the future of their institutions as a simple extension of the past."

Adapting Organizational Structures and Perspectives

Perhaps the most immediate need faced by higher education and industry is adapting their organizational structures so that they foster partnerships rather than hinder them. Like higher education, industry needs not only to clean its house but to reconsider how it has set it up.

Alliances between colleges and the business community require more than better communication between two organizations or groups of people; they also require improved communication within one's own institution. Robert Rosenzweig observes that those executives who make decisions about corporate philanthropy are seldom the same people who make decisions about corporate research expenditures. Often they compete for the same dollars within their company. Many of them fail to realize, however, that cooperating in university research and providing philanthropic contributions to higher education need not be considered as two entirely different projects. "Internal corporate problems of this sort," says Rosenzweig, "limit the development of partnerships." Such problems, however, are more than simply internal. They also hinder a university's ability to gain access to and communicate with appropriate people in the corporate structure.

Some high-tech companies do have a history of good relationships with education. IBM, Hewlett-Packard, Digital Equipment, and Polaroid, for example, are companies that have had longstanding ties to education. The commitment comes from the top, from the chief executive officer or founder of the company, and permeates the entire organization. Commitment of this kind tends to foster permanent and ongoing relationships."

However, high tech as a whole is not a mature industry. As a consequence, surprisingly few firms have nurtured strong and enduring ties with educational institutions. The majority of high-tech companies are both very small and very new. Change in this field is endemic. In addition to mergers and business failures, there are numerous spin-offs, part of the strength of high-tech industry. Moreover, there is intense pressure to develop new products. Data General, for example, puts out a new product every 10 to 12 working days. Their cash needs to go into research and development because of intense competition. We know that in 10 years nearly all of our colleges and universities are still going to be here. By contrast, half of the current robotics companies will probably not exist in two years. They will either have been bought up by another company, have changed their present organization or product line, or have failed. Indeed, the very nature of change in high technology is such that these industries may not mature in the same fashion as industries in the past.

The consequences are quite clear. Universities find it difficult to develop a partnership with a firm that may not be around in two years. Likewise, corporations often do not have the foresight or fortitude to look beyond immediate exigencies and cultivate such "intangibles" as university relations. "The very innovation that characterizes these firms," says Useem, "undermines their ties with other institutions. The high personnel turnover effects not only engineers but also the individual in the company responsible for liaisons with educational institutions. It takes a long time to develop trust in relationships between business and industry. When the key contact at the corporation leaves, many relationships and cooperative projects are immediately in disarray."

Although there are a few notable exceptions, such as IBM and Digital, most high-tech firms have yet to institutionalize their relationships with educational institutions. This results, at best, in fragmentary relationships. For those seeking to develop a partnership with a company, the key question becomes, "Where do you go, how do you gain access?" "Contacts," says Useem, "tend to be haphazard, piecemeal, or determined by a personal relationship—someone you know in your community or some kind of personal tie that will give you an 'in' to that company." Moreover, those people who are edcuationally oriented, those who really want the partnerships to happen, may not have high status or be in a position to commit company resources. If the commitment isn't there at the top, then those who work on educational relations are not rewarded within the company. Unlike those in finance, marketing, or R&D, theirs is often a low-status job. As a result, says Useem, "educators can develop a wonderful relationship with someone in the company that will have no consequence. They can go through a series of 20 meetings with a middle-level executive and then discover that this person doesn't have any clout."

The obstacles to partnerships created by a corporation's outmoded policies and procedures have a severe effect on all but the most elite educational institutions. It is one thing if you are the president of a front-rank research institution and you have a good relationship with the vice-president of a large high-tech company. But it is quite another if you are the president of a small community college or of a regional state university that is attempting to get an engineering program off the ground. The problems encountered by these less-elite institutions are symptoms that alert us to barriers in the corporate structure—internal barriers that hinder a company from forming the very partnerships that will enable it to meet its own needs.

Adapting a firm's organizational structure to improve internal communication and provide access to educational institutions entails more than consolidating a few offices or reviewing the corporation's organizational flowchart. It requires a fundamental shift in perspective. The company must be willing to look beyond short-term exigencies and recognize long-term goals and strategies. Donald Fowler's (1984) extensive survey on the impediments that hinder university-industry relationships disclosed that both university and industry respondents clearly felt that industry's primary orientation toward the short term was a serious obstacle. While industry executives themselves recognize the shortsightedness of this policy, the overwhelming pressures of the marketplace and the financial bottom line make it difficult for them to change. This is as true in human-resource development as it is in research and development.

The competing demands of long- and short-range outlooks have a substantial effect not only on a firm's philosophical outlook but on its daily operation. Jordan Lewis writes that "long-term survival and growth require constant efforts to reach out and grasp tomorrow's technologies and markets before competitors have foreclosed the opportunities, while simultaneously working to improve today's products and production processes. These parallel long- and short-term efforts can be frustrated if management has myopic views of the future or if the firm is unable to draw fully on all available knowledge" (1982, p. 1206). However, the struggle between long-term endeavors in planning and research and the more immediate interests of marketing and production need not crystallize into an irrevocable opposition. Edward E. David, Jr., makes the important observation that the division between long- and short-range outlook is essentially "a management problem, not a technical one. It is management's responsibility to see that promising long-range research is allowed, particularly among the most imaginative and creative researchers and to encourage an awareness of the larger business environment" (1980, p. 135). Such an outlook enables a corporation to recognize the strategic importance of education. This in turn enables it to adapt its organizational structure to foster and take advantage of this resource.

Rapid changes in the business environment—particularly in high technology—tend to discourage long-term relationships with educational institutions. And yet, to cope effectively with these very changes, business and industry need to develop their close cooperation. Without adopting the internal changes in organization and strategy that will foster these close alliances, industry's need for skilled manpower, new windows on research, and a renaissance in innovation will continue to go unmet.

The Role of Government

TWO RESPONSIBILITIES of government have a direct bearing on industry and higher education: ensuring a healthy economic environment and supporting education and research that contribute to our country's welfare. Only recently has government recognized how closely interrelated these two responsibilities are. If it is to help foster a closer working relationship between these two parties, it must eliminate barriers and provide incentives for cooperative efforts.

Very few, if any, would argue with this view. But the very nature of politics thwarts this effort. Minnesota State Representative Gordon Voss comments that "having arrived at the easy conclusion that we in government are major actors in developing or blocking interaction between higher education and industry," we must reflect "on our limits as effective actors. In theory, government should be an effective manager of our society. In practice, we are severely limited. It is difficult to maintain long-term planning in a political environment. Politicians must deliver in time for the next election. As a result, we tend to be crisis and fad-oriented." Colorado Governor Richard Lamm notes that the crisis nature of politics results in "short time horizons and, even worse, in a tendency—like Von Paulitz's generals—to fight the next war as they fought the last."

While government may at times be a good fire fighter, its reputation as an architect leaves something to be desired. All too often its policies reflect old interests rather than encourage new endeavors. Moreover, the possibility forever lurks that new initiatives to encourage industry-university cooperation might themselves become a conduit for pork-barrel subsidies. As Voss makes clear, maintaining and protecting initiatives on a long-term basis is far from easy: "Long-term programs rise and fall with fair rapidity in our political system. It takes a great deal of buttressing to maintain them. High-tech programs are unlikely to escape the pitfalls as well. If we are to prevent this from happening, we will need people with courage and foresight to maintain long-term perspectives and priorities even though they may not fit well into the political system."

Federal Government

In addition to supporting basic research, managing the economy, and formulating national policy, the federal government can take specific actions that will promote cooperation between industry and higher education. These include offering tax incentives, eliminating barriers, acting as a catalyst to promote alliances, and inviting cooperation in its own research endeavors.

Tax incentives have long been on the books. The Economic Recovery Act of 1981 is but a recent example of efforts to employ tax incentives to encourage support of higher education. However, for reasons that are not entirely clear, industry has yet to take full advantage of them. The elimination of barriers elicits far greater attention. "Congress and the media are preoccupied," says Monte Throdahl, "with a no-fault, zero-risk mentality. The prevailing wisdom seems to be that 'what is not explicitly regulated must be bad.' This course is pursued without a concern for similar consequences arising from the wrong use of scarce resources, or with a concern to find new ways of dealing with the changing matrix of economics and politics." While deeply committed to such issues as environmental protection, Throdahl notes that regulatory efforts are often misdirected and inefficient. "A pluralistic society carries some costs for our economy. The heat and light generated by conflict over social and environmental problems takes energy away from growth. Many of our brightest, most energetic people spend their time arguing with each other over the fine points of regulation, often involving trivial data that have little significance. Even worse is the use of scarce capital and other resources to solve what are often nonproblems."

In recent years the federal government has taken on a new role, that of catalyst. John Slaughter describes this effort as "prompting universities and industries to closer relationships and providing certain financial support to set cooperative research projects in motion." This role reflects a gradual change in attitude from government as "doer" to government as "facilitator," with the private sector now taking a more active part.

Several programs at the National Science Foundation illustrate this new role for government. In addition to the Small Business Innovation Research Program, NSF supports Industry/University Cooperative Research Projects, which address specific problems of interest to both university and industrial scientists. The projects are generally funded for one year under renewable contracts. NSF also supports Industry/University Cooperative Research Centers, for which it provides seed money and technical assistance in planning and development, with industry eventually assuming support of these centers as NSF phases out. For instance, industry has been involved in research in polymer chemistry at the University of Massachusetts and at the Polymers Processing Center at M.I.T., and in computer graphics at Rensselaer Polytechnic Institute.

The center at Rensselaer, for example, focuses on problem-solving research that can benefit industry. Grumman Aerospace developed a new space antenna there, and Bethlehem Steel solved a rolling problem through use of computer graphics. "Graduates at the RPI center," says Slaughter, "are highly sought after. In fact, too many leave after only earning the master's degree. Through work at the center, they have learned to understand how industry works. They can easily transfer right into the industrial setting."

In addition to facilitating cooperative ventures between industry and higher education, the federal government is also seeking to enlist university and industrial scientists as partners in its own research effort (Morone and Ivins 1982). As Howard Sorrows of the National Bureau of Standards observes, "The federal government is paying the price of admission to get into the R&D club." The network of federal laboratories is extensive, with 63 laboratories having more than 500 on their staff, 48 with more than 1,000, and 23 that have more than 3,000.

The Federal Laboratory Consortium was established in 1974 for the purpose of making its R&D available to industry, universities, and other government laboratories. It formed a network to make these results available and to provide a national forum for the exchange of technology. Moreover, in 1980 each of the major federal laboratories established its own Office of Research and Technology Applications. The purpose of this office is to make available to the private sector the technology and research stemming from that particular laboratory. Describing cooperative research arrangements at the National Bureau of Standards, Sorrows notes that the Bureau now has about 125 industrial research associates and about 750 people from the university community, among them graduate students. Through the presence of industrial research associates, a company can expand its research base without very much expenditure. Some industrial research associates stay for several months, others; like the American Dental Association, have worked with the Bureau for 50 years.

Although it is encouraging to see the federal government facilitate cooperation between industry and higher education, traditional forms of support are more crucial than ever. "We must recognize," says Slaughter, "that despite the promise that industry-university partnerships hold, they will not take the place of government support for research. Scientists in both communities have a responsibility to work for a steady increase in government support for basic research—support that is not subject to changes in the political and economic climate. University-industry cooperation should augment, not diminish, government support for research."

State Government

Because of our tendency to look to Washington for policy direction and large programs, we may not be fully aware of the substantial contributions made by state governments. They are not only the principal supporter of higher education in the U.S. but also fund many specific economic-development projects.

The policies of state-supported educational institutions are inextricably woven into the fabric of state politics. Even where this relationship does not hold, as in the case of private educational institutions, the need to involve state government goes beyond any real statutory ties government has with the educational community. For these reasons, we should include as partners in alliances between industry and higher education the governor and state executive offices, the state legislature, and those entities of local government that work closely with the state in educational and economic policy.

While the federal government is responsible for funding research, state governments have the duty of providing adequate funding for core programs, not merely in engineering and the sciences but throughout the university curriculum. Economic pressures and the intense interest in high technology exert special influence on state governments that may tempt them to pursue special programs at the expense of core funding. Voss illustrates this point by recalling that the governor of Minnesota recently announced that the state would soon start two new engineering schools. Voss voices concern, however, that the existing engineering school is already short of funds and that other areas of the university curriculum receive very inconsistent support.

Under pressure to stimulate local economies and produce new jobs, many governors are pinning their hopes on wooing high-technology industry into their state. Indeed, governors are leading the call for change in education and for greater cooperation with industry. Concerned about unemployment and preoccupied with questions of economic development, many governors are asking, "What can we do to attract high-technology industry? How can we keep these companies? How can we help them expand?" The survival of their states as well as their own short-term survival as governors depend upon economic growth. Recent inaugural addresses by governors made the connection between an educated labor force and their states' economic survival. As Governor Lamm puts it, "The state that is second best in higher education will be second best in economic development." There has been unprecedented activity in state government to foster the conditions suitable for high-tech growth. The National Governors' Association has sponsored meetings and committee work on the topic, and about half of the governors are actively working with advisory councils on high technology.

Governor Lamm notes great interest among other governors in what might be called "the Silicon Chip Super Bowl." But he cautions that "those who compete to become the next Silicon Valley are not preparing for the future. Silicon Valley is not necessarily the model; that game has already been played; that's yesterday's Super Bowl. We must look to the future and emphasize those things that we have particular strength in. I might add that each state ought to play to its strengths, for I doubt very much if anyone can win a game that other people are already excelling in."

Why do governors have such a vital role to play? "We may not be among the primary managers in either education or in industry," says Governor Lamm, "but we can appoint farsighted people. We can bring leaders from both groups together; we can lead our state agencies toward cooperative support of this important alliance between education and industry. Moreover, we can use the bloody pulpit to advocate this alliance and maintain a balance among the several partners."

Through their leadership and their advocacy of long-term programs, state governors can have a substantial impact on alliances between industry and higher education. For example, the foresight and leadership of successive governors was instrumental in the creation and development of the North Carolina Research Triangle. Moreover, the long and at several points difficult history of the Triangle serves to remind other states that they cannot expect their recent efforts to bear immediate fruit. Although the Triangle is essentially a cooperative venture between industry and higher education, Don Phillips notes that the involvement of state government was a particularly important factor. "It was through Governor Luther Hodges that the Research Triangle Committee organized. While the state had a vested interest in the success of the program, it wasn't going to operate directly any of the institutions or organizations. State government, in short, played a substantial catalytic role, a convener role, to get the parties together and keep the momentum going. Through the leadership of the governor it is possible to focus resources, individuals, and institutions within the state on opportunities and problems of particular importance. This can be done not by playing a direct role, not by having any administrative or bureaucratic control over the process, but by bringing the parties together and mobilizing their efforts."

While governors may propose, it is nevertheless within the purview of legislators to dispose. State houses are experiencing considerable political pressure to invigorate their states' economies by promoting high technology. They would be well advised, however, not to forsake thoughtful, long-term initiatives in an effort to attain quick results. Looking to the future, Voss predicts that "legislatures will overwhelmingly choose to be catalysts in building partnerships between state-supported institutions and the private sector. 'Leveraging' will be the buzz word that describes their fiscal policy. Legislatures will put out challenge grants to institutions that require matching money from the private sector. Conversely, higher-education institutions will seek challenge grants with matching requirements as those institutions bid to stay alive in a period of falling enrollment." Innovation centers will be created, says Voss, but not at the astronomical rates of the early 1980s. State agencies promoting high-technology financing will also play an important role.

Local initiatives and leadership are necessary if long-term policies are to have broad, continued support among industry, education, and government leaders, whatever their political persuasion. Partnerships, we might add, are far too important to become partisan affairs.

The Role of Third Parties

"IN EVERY HOUSE OF MARRIAGE," writes the poet Stanley Kunitz, "there's room for an interpreter." Indeed, Pat Hill Hubbard counsels third parties not to become a "marriage broker" between industry and education. "The two are very less like people than they are like countries—two separate, yet symbiotic, cultures that require the other's presence and need to keep their balance of trade even. Instead, a more appropriate role for a third party might be described as that of a shuttle diplomat." The purpose, then, of third parties is not necessarily to erase differences but to coordinate them and develop from them effective alliances. Third parties are frequently in a position to mediate effectively, dispel distrust, and help the partners sort through their different goals and values as they search for common ground.

Third parties can provide invaluable assistance to industry and higher education on two fronts: gaining access, and matching needs with resources. As we have already observed, outmoded institutional structures and the haphazard nature of personal contacts often hamper access to the right person in industrial or educational organizations. Third-party groups can significantly enhance collaborative efforts by providing a structure, staff, and other support mechanisms that bring managers and the educators together. "Without such facilitators," notes Elizabeth Useem, "joint ventures of various sorts will remain largely confined to a select group of universities and a few large corporations." Harvey J. Edwards considers access the primary reason why there isn't more cooperation among business and colleges. "How do you make contact and with whom? How do you find that person and how do you present your case? With the help of a third party, both groups have easier access. The access problem that you face in a university or corporation can best be resolved, it seems to me, by a neutral body." Moreover, third-party brokering can help build relationships between organizations, not simply between individuals or between a person and an organization.

In addition to facilitating better access for both industry and higher education, third parties are often in a position to assess each party's needs. Rogers Finch points out that nonprofit societies are aware of research needs in the field of their technical interest and can locate the resources to conduct the desired research. Many times there is no one company interested or capable of conducting research in a particualr field, but many are interested in supporting the research on a cooperative funding basis. Societies can also insulate firms from the antitrust problems associated with industrial cooperative research ventures.

Like the very partnerships they are promoting, brokers must be oriented to the specific needs of both parties in the community they serve. Effective brokering, says Edwards, is "demand-driven": "We are not walking in and saying, 'Here's the list of courses that these 13 schools offer—which ones do you want to buy?' Instead we are saying, 'What do you want? You define it and then schools will custom-tailor it if necessary to give you what you want.' That means taking out a chapter, adding specific topics, or teaching in a different manner. Companies like that and will respond to it."

Effective brokering can also consolidate resources, thereby helping a company make more efficient use of its training dollar. Under a typical tuition-reimbursement plan, 40 people a year may take a basic accounting course, but they may do so through nearly as many different educational programs, some of questionable quality. However, if the training director can specify what topics should be covered in a course so that it will truly match the needs of the company and its employees, this course request can then be matched with a college that offers a similar course. Payment for the course may still come from the company's tuition-reimbursement program. Even if there is no difference in the actual dollars spent, there is considerable difference in the quality control that the training director is able to exert and the relevance of the education to the needs of the company.

As we focus in greater detail on the role of third parties, it may be helpful to distinguish between three groups that engage in brokering efforts: industry, trade, and professional associations; brokering efforts in higher education; and local, state, and regional associations. We will also touch upon the role that third parties can play in forming political alliances to promote the common goals of industry and higher education.

Industry, Trade, and Professional Associations

The common interests of engineers in industry and in academia and their desire for greater interaction prompted the formation of trade and professional associations in the late 19th and early 20th century. The history of these organizations reflects a long-standing interest in partnerships between industry and higher education. High technology has only increased the need for such collaboration and has encouraged these associations to intensify their efforts. Recognizing that an increasing number of engineers have become technologically obsolete due to rapid developments in their field, technical societies are turning to college campuses for help in constructing training courses and making them available to their members.

Over the years, engineering societies have identified areas in their respective disciplines that needed research efforts and have obtained funds from industry to enable this work to go forward. Most of this research funding flows to faculty at colleges and universities and has become, notes Rogers Finch, "a significant element in supporting graduate training and research in areas for which federal funding is not available."

The shortage of engineers has prompted the American Society for Engineering Education to undertake a faculty shortage project under a grant from 10 major corporations. Its principal objective is to encourage industry/university cooperative programs. Among its recommendations is greatly expanding graduate fellowships to attract and retain the best talent in the teaching profession. Professional associations are also working with retiring scientists and engineers to place them in university teaching positions. Some take full-time positions, and others serve as part-time adjunct faculty members. Moreover, many individual societies are establishing educational endowments.

Brokering in Higher Education

The efforts of individual administrators to attract industrial support and establish cooperative ties have depended largely on tenacity and a great deal of footwork. Rather than facilitating this process, organizational structures within the university tend to present themselves as obstacles. Because contacts are generally personal, and as a consequence haphazard, the brokering effort within higher education has had rather mixed results. While partnerships between major research universities and large corporations receive a lot of press, the efforts of smaller, less visible institutions have met with only partial success. If alliances are to grow and mature, brokering efforts within the entire higher-education community must be improved.

In describing his experiences at Ohio State University, George Baughman presents a picture that would apply to a good number of institutions. When Baughman moved into his role as institutional gadfly, promoter of innovative programs, and broker for alliances with industry, he found that channels of communication were not at all institutionalized. Not only did the university know very little about the needs of industry, it also knew surprisingly little about its own programs and about faculty contacts with the business community. Strengthening these existing relationships and fostering new partnerships were no small tasks, especially because brokering arrangements were not in place. As Baughman reminisced, "It was sort of like Lucy putting up a sign that says 'Consulting, 5 cents.'"

In his effort to organize lines of communication and promote alliances, Baughman found that his first task was to catalog the initiatives already underway at the University and those areas where there might be new opportunities. In turn, he worked with the chamber of commerce to catalog the needs of local business and industry. This efficient and organized brokering effort resulted in matching up needs with resources far more successfully. Baughman lists three principles that have guided his work: "Start off with a loose definition of what cooperation is and who you know you are going to work with. Secondly, emphasize faculty-based activities. The third principle is that it is very important to have a broker to make these kinds of things work. That broker has to understand not only the needs and interests of higher education but also industry's perspective."

Robert Rosenzweig emphasizes, however, that successes at a handful of institutions must be translated into more effective efforts throughout higher education. "If we want decisionmaking that is both decentralized and intelligent, then we have to be prepared to collect and make available the knowledge on which sound decisionmaking must rest. There is a growing body of experience that could be of value to others facing similar situations, but it first must be collected, organized into useful form, and made available to those who need it. The Association of American Universities (AAU) has committed itself to undertaking that task. In cooperation with other interested groups, the AAU will seek support for the establishment of a national clearinghouse for the collection and distribution of policies and practices bearing on industry-university cooperation. It is the responsibility of the faculties, administrators, and trustees of each institution to generate appropriate policies and to ensure that they are followed in practice. It is the collective responsibility of universities to assure that each institution is armed in its deliberations with the knowledge of what others have done." The American Association of Community and Junior Colleges has likewise been quite active in promoting alliances with industry and in gathering and disseminating useful information about partnerships.

The National Center for Higher Education Management Systems (NCHEMS) is committed to helping colleges and universities improve their management capabilities in an era of rapid technological, economic, and educational change. Through its nationwide base of experience in industry/university partnerships, the Direct Assistance Program at NCHEMS has helped institutions and industries develop cooperative relationships. As the only national center devoted exclusively to R&D in higher education, NCHEMS frequently has been called upon to serve as a "broker" to help "parties-at-interest" work through issues pertaining to industry/university alliances.

The birth of an engineering school at SUNY-Binghamton illustrates the important role that a third-party broker can play. The initiative for the engineering school came in large part from the business and industrial community in Broome County, New York. The academic community in Binghamton was "interested," but not totally convinced, that a school was necessary. Both parties, however, required help in adequately assessing the needs and possibilities for an engineering program. NCHEMS assisted in this effort to determine supply and demand. It collected data and information from industries in the Binghamton area about their needs for additional educational programs. In turn, it compared local educational opportunities available within other centers of high technology in our nation. Moreover, the NCHEMS project team looked carefully at opportunities available to high-tech employees and students in the Binghamton area who themselves want to enroll in engineering programs in New York state.

Ted Mulford, a leading figure on the Broome County High-Tech Council, considers the impartial studies and recommendations of NCHEMS to have been instrumental in establishing the engineering school in such a short period of time. Mulford relates, for example, how the majority leader of the state senate, who is from the Binghamton area, was able to say to people, "Look, this is not my project. I didn't develop it. The SUNY-Binghamton people didn't develop it. It came from business and industry." The proposal won widespread endorsement because the engineering program was not the pet project of one institution and because the study of supply and demand had been conducted by an independent, nationally based center with expertise in higher-education management systems. In the words of Mulford, "The

NCHEMS imprimatur on the proposal was exceedingly important in its acceptance by people in the state organization." The efforts of NCHEMS on behalf of university-industry partnerships are but one example of brokering in higher education.

Local, State, and Regional Associations

Area associations have provided a means for industry and higher education to relate their interests to pressing local and state needs. These associations are formed in the public interest and are often quasi-governmental in nature. They are competitive in the sense that each attempts to attract economic development to its area of the country. Their active and effective role derives from their ability to focus on regional and state needs.

Minnesota Wellsprings, for example, is a project involving state leaders in business, labor, education, and government. "The purpose of the group," explains Representative Voss, "is to expand Minnesota's technological leadership and to increase the generation of new jobs." Minnesota Wellsprings intends to develop new policies to solve specific problems, including the adaption of business, schools, and society to new technologies; competition from foreign companies; shortages of skilled workers; and the difficulties facing entrepreneurs in starting a small business.

Minnesota is by no means alone in its attempt to attract high-technology industry by developing educational infrastructures and improving the business climate. Numerous programs and initiatives are underway in most states, each with a slightly different emphasis and intention. The Bay State Skills Corporation, for example, is a state-funded, third-party group in Massachusetts that brings together schools and companies in training relationships. The Industrial Technology Institute is an independent, nonprofit corporation established to help improve the future economic health of Michigan. A research and problem-solving organization, the Institute is seeking to become a world-class institution devoted to the factory of the future. Its goal is to make Michigan a center of modern manufacturing, both as a user and maker of tools. Organizations and institutes such as these are being rapidly formed, often at the behest of high-technology task forces organized and appointed by state governors. So intense have such efforts been that the National Governors' Association has prepared a compendium of state activities that encourage technological innovation.

Local and state roundtable groups can also focus the energies of alliances on improving general education, particularly at the primary and secondary level. Although noting the well-intentioned efforts of a variety of national associations and groups, David Saxon stresses the need to work at the local level and understand local needs. "There are more than 1,000 school districts in California, more than 16,000 in the nation. You can't solve the problems of our schools by pronouncements or dicta from a central body. You have to get into the local communities. It is our intent to develop what we call local networks, to go into these communities, and to bring educational and business leaders together so that they can address their problems in light of their impact on the community."

Third Parties and Political Alliances

In their role as shuttle diplomats, third parties can also be instrumental in forging political alliances between industry and higher education. These alliances serve two functions: they can lobby government for support and changes in policies, and they can also inform the public about the pressing needs of industry and higher education. Political alliances are particularly important because government has yet to understand the special needs created by high technology. As a consequence, government programs are often ineffective, as are traditional lobbying organizations. In an article on the political context of the high-technology boom, Jerry Hagstrom reports that "high-techers" charge that "politicians rarely understand the mix of engineering talent, capital and entrepreneurial spirit that makes their industry tick. They believe the elected officials are offering outdated assistance that might work for the steel and auto industries or traditional small businesses, but not for them" (1982, p. 861).

Elizabeth Useem, among others, contends that "the partnership that is most important is the political alliance that needs to be developed between business and education." Citing as an example the Proposition 2-1/2 campaign in Massachusetts, Useem recalls how the lack of a political consensus divided the educational and business communities, thereby causing a good deal of bitterness. She notes that were it not for the support of the Massachusetts High Tech Council, this tax-cutting initiative would have been defeated. The substantial role that high-tech companies had in the passage of this proposition was not lost on educators. Adds Useem, "I can't tell you how bitter they are against the companies. We talk about partnerships, but I could hardly get interviews sometimes because people thought I was from a high-tech firm. This very poisoned relationship is now getting better, but those teachers and administrators who are politically knowledgeable are still bitter."

While the absence of a political alliance can be damaging, vigorous cooperative efforts can likewise have a profound impact. Useem offers another example from Massachusetts, this time a successful one: "Three members on our board of regents are from high-tech companies. They have done their homework and, as a consequence, have been very effective. When visiting schools, they were appalled at what they saw—community colleges with little money to operate and students lined up at computer terminals at four-year colleges. As a result, they went to bat for education; they went to the governor and lobbied for more money for higher education. The money did come through and was largely allocated for programs in high-technology and health. This funding prevented liberal-arts programs from being retrenched, a point that liberal-arts faculty rarely understand. They complain about additional funding for technical programs but forget that this means technical programs can be developed without severely reducing those in the liberal arts."

Speaking of the new engineering program at SUNY-Binghamton, Paul Bradley christened it "The Miracle at Binghamton." Seventeen months from idea to the reality of a budget is no small feat in the State University of New York system, which is anybody's idea of a tough bureaucracy. "It happened," adds Bradley, "because business got behind it. In fact, business kept saying to education, 'get out of the way, we don't want you to appear self-serving. We'll go up and meet with the governor, we'll go up and meet with the legislature, we'll even meet with those folks in the Bureau of the Budget. We're going to convince them why we need an engineering school here'." Political alliances of this sort are essential to improved partnerships between higher education and industry.

Neither business nor the academic community carries the master key that unlocks the creative potential of partnerships. Efforts to initiate alliances must necessarily involve both parties. Examples of successful collaboration teach us how important and effective strong alliances really are when based on a mutual understanding of needs and interests.

"More important than the fine print is the attitude that partners bring to an alliance. Essential to effective collaboration is a climate that encourages an unhindered flow of new ideas, a willingness to confront differences as they arise, and a desire to arrive at solutions in spite of the obstacles that may present themselves."

Chapter Three

Partnership Arrangements

The Spectrum of Possibilities

EACH PARTNERSHIP between industry and higher education is like a unique fingerprint. We can read in its distinctive pattern not only the needs and interests that both parties bring to the alliance but also their shared concerns. This diversity requires that we evaluate each arrangement on a case-by-case basis. "Almost every new arrangement," Donald Fowler points out, "is in some substantial respect different from prior arrangements." Because each agreement is the result of very specific needs, there are few if any "best" ways of handling the variety of problems involved.

When reviewing the experiences of others, however, we cannot forget that our own requirements are equally specific and will demand creative solutions. As Fowler points out, this is an entirely positive situation: "One of the really attractive features of university-industry relationships, as contrasted with the traditional arrangements between universities and the federal government, is the range of diversity that is possible. Let's take advantage of that."

Although there is no set pattern to arrangements between industry and higher education, it would be useful to distinguish a variety of essential types, and thereby gain an understanding of the spectrum of possible relationships. Elisabeth Zinser has offered one such typology. Its purpose, she explains, is "to propose a framework for conceptualizing traditional and emerging models of industry-academia relationships, and to analyze the most prominent issues in creating such ties." Listed in table 5, the categories

Table 5

A Typology of Industry-Academia Collaboration

Distant Interaction
(Greater autonomy, limited obligations)

1. Contributions (Philanthropy)
2. Procurements (Purchases)
3. Linkages (Networks)
4. Exchanges
   - a) Technology Transfer Programs
   - b) Industrial Liaison (Affiliate) Programs
5. Cooperatives
   - a) Peer Collaboration
   - b) Research Agreements
   - c) Research Consortia
   - d) Research Centers (University Based)
   - e) Research Laboratories (Industry Based)
   - f) Research-Industrial Collectives/Parks
6. Joint Ventures*
   - a) Joint Research Ventures
   - b) Joint Business Ventures

Intimate Interaction
(Greater commitments and obligations)

SOURCE: Elisabeth A. Zinser, "Industry-Academia Relationships in Research and Innovation: Emphasis on Biotechnology," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.

*Zinser refers to this category as "partnerships" in business and financial sense of the term. Because we have been using the word partnership in a far more general way, we employ here the term "joint ventures."

As described in Zinser's master's thesis, the typology includes two further categories that exist for the most part in concept only, close legal affiliation and unification. See: Elisabeth Ann Zinser, "Industry-Academia Relationships in Research and Innovation: The Case of Molecular Biology" (Master's thesis, Sloan School of Management, Massachusetts Institute of Technology, June 1983.)

progress from more distant interactions that carry limited obligations and maximum autonomy, to more intimate ties that involve commitments, obligations, restrictions, and possibly shared governance. Each category includes a variety of forms for interaction, some traditional and others relatively contemporary. Moreover, these various forms of partnership are not mutually exclusive.

This typology provides a useful conceptual framework in which to discuss the variety of possible alliances. Our intention, like Zinser's, is not to present ideal models but rather illustrations, not to suggest that one level or type of partnership is necessarily preferable but to survey the broad range of existing possibilities. An institution's educational mission and organizational structure may suggest that certain alliances and levels of commitment serve its interests better than others. Likewise, a company's specific needs will indicate that certain forms of collaboration might be more appropriate. Each of these vehicles for interaction, however, can have important things to offer both industry and higher education.

Contributions (Philanthropy)

Corporate giving is an important source of support to colleges and universities. In 1980-1981, for example, corporations contributed about $778 million to higher education. Universities place high value on these contributions, particularly when they do not carry restrictions. When that is the case, university presidents, deans, or department chairs can channel the funds as special needs arise. Because of their discretionary nature, donations can also serve as seed money for special projects. By attracting additio. .l support, they can provide financial help to the university in excess of their actual dollar value.

Unrestricted corporate donations allow the deans of engineering colleges to make some rather remarkable changes. The University of Colorado at Boulder, for example, recently hired six computer-science Ph.D.'s, a remarkable feat given the shortage of faculty in this field. The University's Director of Engineering Development stressed that attracting these new faculty members would not have been possible without the discretionary money received from corporations.

Other kinds of corporate philanthropy include contributions of restricted funds and equipment donations. Restricted funds are generally targeted for such purposes as construction, endowments, endowed chairs or professorships, student scholarships, research assistantships, and research funds for faculty. The effectiveness of such contributions depends in large part on the degree to which the corporation understands a college's actual needs. This is no less true of equipment donations, especially in the case of computers and related systems.

Universities also make valuable service contributions to corporations and industry generally. Such contributions include public seminars and lectures, reports of research activity, access to facilities and libraries, and placement services. Philanthropy and public service are important activities. But because they do not require or develop substantial contacts between industry and higher education, both parties are realizing that they are not an especially effective means of fostering collaboration.

Procurement (Purchases)

Both firms and universities purchase services from one another to meet specific needs. Industry often procures from the university such services as consultation, product testing, special education or training courses, and the use of special equipment and facilities. Likewise, universities can also procure services and facilities from corporations that have superior expertise or equipment. A corporation, for example, may offer the use of its state-of-the-art CAD/CAM equipment at cost to a nearby university after business hours.

In one sense, procurement is not an especially intimate form of cooperation between industry and higher education. But the provision of services for a fee rendered can develop closer ties if these procurements take place over a long period of time and the parties become well-attuned to each other's needs. The following two programs illustrate how this mechanism can contribute to substantial alliances between industry and higher education.

- Pratt & Whitney, which manufactures jet engines, approached Manchester Community College in Connecticut for assistance with its apprenticeship program. The College redesigned the program and offered on-site courses with twin sessions before and after working hours. As an adjunct to this program, new apprentices were also able to earn an associate degree after successfully completing additional credits at the College. Their initial arrangement was extended under a five-year contract between the company and the College.
- In Portland, Oregon, an innovative alliance has been established between the city, Portland Community College, and Wacker Siltronic, a German-based manufacturer of silicon wafers. Using CETA funds and the resources of the College, Wacker was able to staff its new manufacturing plant from a pool of unemployed Portland residents. The printing industry in Portland has started discussions about a similar program.

The above examples indicate that the procurement process can contribute to better partnerships between industry and higher education, provided the contacts are appropriately nurtured and developed.

Linkages (Networks)

Linkages are mechanisms to promote communication and problem solving between industry and higher education. While they can also include informal networks, our chief interest lies in linkages on the organizational level. One typical linkage mechanism between the university and corporations is the sponsored-program office. Such an office manages activities related to research contracts and other sponsored projects, including the identification of research endeavors of potential common interest to academia and industry. It helps negotiate research contracts between parties, monitor ongoing activities in light of policies at the institution, facilitate communication, and resolve conflicts. Likewise, many firms are establishing central offices to promote university relations in the areas of research and human-resource development.

Liaison activities can also be instituted at the school and at departmental levels, where they would ensure better communication between a specific industrial sector and a specific group of researchers within the academic community. Even small community colleges can promote and safeguard these linkages by establishing offices on the organizational level. For example, Bay de Noc Community College in Escanaba, Michigan, operates a program exclusively devoted to contracting with business and industry. While large corporations find it helpful to have a central office to monitor their relations with higher education, small and medium-sized businesses will find it to their advantage to establish, if not offices, at least formal liaison procedures.

University/industry R&D offices provide another example of linkage mechanisms. These offices help match the needs and capacities of the industrial sector with those in the educational community, especially at a large research university. Examples include the University/Industry Research Program (UIR) at the University of Wisconsin at Madison. It encourages Wisconsin's industry to utilize emerging technologies more fully and serves as a connection between the university's research programs and interested corporate parties. The University of Michigan operates a similar program, called the Industrial Development Division. It provides a channel through which business can gain access to faculty and their research activities, and through which potential cooperative projects can be explored.

Exchanges

While linkages are mechanisms to promote communication and problem solving, Zinser defines exchanges as "formal relationships involving the trade of tangible assets."[7] Exchanges between academia and industry include the sharing of scientists, where their expertise has reciprocal value, as well as the exchange between organizations of knowledge and tangible value, usually financial. Systems of exchange range from highly sophisticated programs to ad hoc bartering arrangements. Although mechanisms for exchange vary, they serve to form effective and close alliances when the actual needs of both parties are being met.

A case in point is the cooperative arrangement worked out by former president Brent Knight of Triton College and the Society of Die Cast Engineers to establish a die-cast training facility on its campus. The 7,200 square-foot Die Cast Center houses the society's national headquarters, a die-casting laboratory, and classrooms. The building was paid for by the Society, which uses the facility to conduct national continuing-education programs for its members. Triton utilizes the lab, its die-casting equipment, and the classroom space for the benefit of students enrolled in its die-casting program. This cooperative venture allows the Society to have sufficient facilities to hold training programs on a regular basis, while providing Triton the opportunity to establish a die-casting curriculum that would have been otherwise impossible because of prohibitive equipment costs.

Innovative bartering arrangements can also prove very useful, particularly in tight economic times. Corporations and colleges may have various assets that they are not utilizing fully—assets that may perhaps meet the needs of the other party. Bartering arrangements tend to be ad hoc solutions to meet these immediate and very local problems. One of the many obstacles to such arrangements is establishing a "coin of the realm," that is to say, agreeing on how many apples will be worth how many oranges.

Two examples more appropriate to the interests of major research institutions include (1) technology-transfer programs and (2) industrial-liaison (affiliate) programs.

1. Technology-Transfer Programs. Many campuses have established programs to facilitate and manage the transfer of new discoveries to industry for commercialization and to return value to the university, usually in the form of royalties.

Some universities have established their own offices, while others utilize a variety of external mechanisms for brokering technology. Stanford University, for example, has set up the internal Office of Technology Licensing to manage the identification of potential licenses and the negotiation of licensing agreements. They grant exclusive and nonexclusive licenses, depending on the circumstances of the patent and the need for exclusivity in that product's development. The office is able to support itself by taking 15 percent off the top of income it generates. The remaining 85 percent is allocated based on Stanford's policy—one-third to the school, one-third to the department, and one-third to the faculty member who invented or developed the technology.

Some universities use external licensing mechanisms to broker their technology rather than an internal office. We can speak of four such mechanisms. The first takes the form of an independent, nonprofit, campus-based research foundation. Such a foundation can license patents extending from university research and return most of the royalties back to the university, retaining a percentage for its own operation. The foundation can also serve as an insulator or buffer between the university and industry, as well as a broker to enhance the value of royalties through investments. The most well known example of this kind of mechanism is the Wisconsin Alumni Research Foundation. A second mechanism is a private research corporation that can encourage and sponsor the licensing of university inventions. A third option is a private consulting firm that can act as a research or technology broker between universities and industrial firms, leaving the licensing details to the parties involved. A fourth mechanism is government-sponsored programs organized to facilitate and channel university research. One such program is designed to channel research in the field of energy to local utility companies.

In addition to the possibilities outlined above, several new ideas are developing in the area of technology transfer. Zinser describes the emerging concept of a "technology pool," whereby an independent foundation or organization would manage patents and licensing arrangements for a group of participating universities. Income from royalties and an investment portfolio would be distributed among the various universities in an equitable manner. The intent of this concept is to remove actual or perceived conflicts of interest. Moreover, such a foundation could gain value from and prevent secrecy in the use of technology that, while patentable, cannot be easily protected. The latter phenomenon, adds Zinser, is especially troublesome in the field of biotechnology.

2. Industrial-Liaison (Affiliate) Programs. These programs provide industry with efficient and timely access to research expertise, and return financial value to the university for such access. Participating companies belong to the programs by paying an annual fee, for which they are provided various forms of contact with university resources.

There are two kinds of liaison programs—centralized and decentralized—and each has its merits. "A major advantage of a centralized industrial-liaison program," says Zinser, "is the flexibility derived from the scope of the program and its capacity to shift among fields from one year to the next to address topics of particular interest, which these days include biotechnology and microprocessors. On the other hand, decentralized programs are smaller and more specialized, and thereby offer closer contact, which often leads to joint research projects."

In return for an annual fee of $30,000, MIT's centralized Industrial Liaison Program offers many benefits to member companies, such as systematic and efficient access to research results, consultation with leading authorities, exposure to students, formal conferences, visitations to the firm, and advance notice of research activities. In 1981, the program had 280 member companies. In return for their support, firms gain a window on science resulting from a $331 million research budget.

MIT's decentralized liaison programs function for the greater part at the school or departmental level. An example is the Center for Information Systems Research (CISR), which operates in conjunction with the Sloan School of Management. Members pay $25,000 a year in return for seminars, conferences, interaction with faculty, and exposure to students for potential recruitment. Funds generated are used to support faculty research projects on topics of mutual interest to the university and business corporations. In 1982, Stanford University alone had 21 decentralized industrial-affiliate programs. Firms join for annual dues that run from $5,000 to $100,000 per year, based upon the nature of a particular field and the size and financial position of interested companies. In order to protect junior faculty from undue influence by industrial affiliates, liaison programs developed at Stanford's School of Medicine involve primarily the department's senior faculty. However, funds generated by the program are used to support the research activities of junior faculty, who are excluded from any role in the its consulting activities.

Industrial liaison programs are important because they provide industry a window on research results and, in turn, acquaint university faculty with research problems that are of practical value to industry and to society.

Cooperatives

Cooperative research relationships include a variety of models, ranging from simple collaboration between industrial and academic scientists to complex and formal arrangements involving two or more organizations. We will describe six kinds of cooperative arrangements: (1) peer collaboration, (2) research agreements, (3) research consortia, (4) research centers (university based), (5) research laboratories (industry based), and (6) research collectives and industrial parks.

1. Peer Collaboration. Scientists have often teamed up to collaborate on research. In recent years, however, there has been an increasing trend to provide an institutional framework for such collaboration. AT&T Bell Laboratories, for example, maintains a host of arrangements whereby scientists from industry and academia can interact and pursue research on a variety of topics of mutual concern. However, this kind of peer collaboration in industrial laboratories depends upon an in-house capacity characteristic of only the largest corporations. For smaller corporations and universities, peer collaboration is frequently pursued on an ad hoc basis. Cooperative arrangements of a more formal nature tend to take one of the mechanisms described below.

2. Research Agreements. Research agreements can be defined as contractual arrangements between a university and a firm for the conduct of research in an area of mutual interest. The company provides the funding, usually in return for access to resulting knowledge and discoveries. While the nature of research can vary, most believe that work done at the university should concentrate on fundamental or basic research. Among the issues that frequently come up in the negotiation of these agreements are influence on research direction, licensing, patents, publication rights, and access to information on work in progress.

Among the well-known examples are the 1974 agreement between Harvard University and Monsanto Chemical Company, establishing a 12-year research arrangement, and the 1981 agreement negotiated between Massachusetts General Hospital and Hoechst, A. G. One of the world's largest chemical and drug companies, Hoechst is providing Massachusetts General Hospital with more than $50 million over the next decade, making it one of the largest research grants given to a U.S. university. It will finance a major effort in genetic research, including the establishment of the new Department of Molecular Biology at Massachusetts General and a new facility.

Research agreements of this kind have sometimes been facilitated by a third party, such as a state or federal agency. The National

Science Foundation, for example, had by 1980 funded or facilitated 74 industrial-university cooperative research projects. These projects are judged on scientific merit and on their potential for effective collaboration.

3. Research Consortia. Research consortia represent a mechanism whereby a single university can involve a number of companies in its research program. Member companies pay a fee to support university research activities and supply participants to help in that research. The multifirm approach can reduce pressures that are associated with exclusive contact with a single corporation.

The MIT-Industry Polymer Processing Program provides one example. Although the program began with federal assistance from NSF, it has since become self-supporting. By 1980, it had 12 member companies that had each paid \$19,000 to \$100,000 per year, depending on the size of the corporation. Revenues support 25 research projects as well as graduate students.

4. University-Based Research Centers. A research consortium as described above can frequently develop into a major interdisciplinary and long-range research center. Zinser observes that "one of Stanford University's research consortia contributed for years to semiconductor technology for electronics firms in Silicon Valley. But more recently, the University has created a center to bring its semiconductor research under one roof." The new Center for Integrated Systems (CIS) is being built on funds partially contributed by industry sponsors. Stanford will own the patents on new discoveries, but the results will become available to sponsoring firms through licensing arrangements. Company scientists and engineers will participate in research and contribute new ideas from an industrial perspective. By 1982, the Center had signed up 17 sponsors and had guaranteed commitments of \$20 million for facilities over the next three years. Each sponsor has also agreed to provide \$250,000 per year over the next three years for education and research purposes. Numerous research grants and an \$8 million contract from the Department of Defense indicate substantial government participation as well.

The National Science Foundation has actively supported the establishment of research centers. Referring to a guidebook that NSF recently published on how centers function, John Slaughter recalls that "In just a few weeks, NSF had well over 8,000 letters from universities, industries, health centers, and just about every kind of organization involved with science and technology." Among the centers that NSF has helped establish are the Center for Welding Research at Ohio State University, the Center for Interactive Computer Graphics at Rensselaer Polytechnic Institute, and a Center for Research on Polymers located at the University of Massachusetts. Each center is somewhat different from any other. In the case of the Building Energy Utilization Lab at Iowa State, NSF did not even provide seed money. NSF's role has been strictly that of consultant, of a broker between university and industry. NSF provides actual funds only for the laboratory's evaluator.

A common characteristic of research centers is their interdisciplinary nature. The research interests of participating firms are not likely to be restricted to a single discipline, department, or academic unit but rather cluster around a common technology. As a result, research centers generally involve faculty and graduate students from several departments. This contributes to a more innovative effort not hampered by traditional disciplinary boundaries.

5. Industry-Based Research Laboratories. Although in some ways parallel to a research center at a university, an industrial laboratory is quite different in that the flow of research moves to one firm rather than to several firms or an entire sector of the industry. Only a few industrial laboratories have the sufficient capacity and breadth to establish an arrangement similar to university-based research centers. AT&T Bell Laboratories is perhaps the preeminent example of an industrial research center that calls upon a number of universities to participate in an organized way in their research activities. While many corporations have research laboratories, few have integrated the participation of university researchers on such an institutional level.

However, the example of Bell Laboratories notwithstanding, there does not appear to be the same degree of interest in industry-based cooperative laboratories as there is in university research centers. The likely reason is that in their search for new windows on research, corporations are turning to university research in the hope of stimulating innovation.

6. Research Collectives and Industrial Parks. Research collectives are examples of long-term, broad-based contracts that involve a collection of universities and/or an entire sector of industries. These arrangements are often developed by industrial research and trade associations, such as the American Petroleum Institute, the American Iron and Steel Institute, and more recently, the Semiconductor Industry Association. The purpose of such a collective is to involve several universities in supporting research for an entire industry.

Prompted by their concern that America is beginning to lose its preeminence in semiconductor research, the Semiconductor Industry Association has recently formed a research cooperative. Twenty participating corporations eventually expect to channel about $50 million per year into three to six selected American universities. The intent of the cooperative is to increase by 25 to 50 percent the amount of pure research America devotes to semiconductors and computers, as well as to increase the supply of professionals with advanced degrees.

In an effort to catch up with Japan's head start in developing so-called "fifth generation" computers—those possessing the ability to think—12 large American electronics companies have recently formed a consortium called Microelectronics and Computer Technology Corporation (MCC). When looking for a home site, MCC expressed strong desire to conduct its R&D in concert with a major research university. Austin, Texas, was chosen in large part because academic, business, and government leaders worked closely with one another to present an attractive package of incentives to MCC.

Research parks also represent a powerful means of bringing universities and firms into close association. These parks are often assisted by governmental agencies acting as a third party to strengthen a region's economy. The North Carolina Research Triangle is a well-known example of long-term cooperation between industry, higher education, and government.

Rapid developments in high technology have prompted other regions to consider developing research parks. For example, Rensselaer Polytechnic Institute has recently invested $3 million in real-estate development to attract high-technology industries to a 200-acre tract that they own near campus. The prospects seem lucrative indeed: The development forecasts the employment of 9,000 people with a payroll exceeding $100 million. State income-tax payments are expected to be $5 million, and property-tax revenues to local government are estimated at over $500,000 per year. A number of public and private institutions are actively investigating the prospect of establishing such parks.

We should be cautious, however, in our assessment of research parks. To be successful, the parks must meet the needs of local industry and the academic community, and they must also enjoy widespread and long-term support. They are not a cure-all or a quick solution to difficult problems. Indeed, a recent study commissioned by the Southern Regional Education Board (1983) has found that of 27 university-related research parks established since 1950, only 6 can be viewed as prospering; 16 of the parks have failed, and 5 have an uncertain future. While successful parks are envied by many cities and states, it takes a rare combination of broad community support, extensive educational and industrial resources, and considerable entrepreneurial savvy to replicate these isolated success stories (Magarrell 1983).

Joint Ventures

This category concerns partnerships in the restricted, financial sense of the term. "American universities," notes Elisabeth Zinser, "are seeking mechanisms to attract corporate support through research in a way that allows them to take part in the enormous capital gain that may grow out of their research studies. This effort has led to the creation and consideration of innovative models that take on the characteristics of a partnership." We can distinguish between two kinds of joint ventures: those having to do primarily with research, often through the intermediary of a nonprofit organization, and those having to do with investment and business.

1. Joint Research Ventures. Perhaps the best example of a joint venture in research is the recent creation of the Center for Biotechnology Research at the University of California and Stanford University, together with a new company called Engenics. Engenics is a new bioengineering firm interested in the mass production of genetically altered organisms. The nonprofit Center for Biotechnology Research will support biotechnology research at the universities. In turn, the company Engenics will build on that research to create a business in genetic technology. The nonprofit center represents a buffer between the universities and Engenics.

Six major corporations contributed to the $10 million raised to create the Center and Engenics. The Center will be provided exclusive license to patent rights emerging from university research financed through the Center. In turn, exclusive sublicenses to exploit these patents and discoveries will be available to the six sponsoring firms and to Engenics at commercial rates. Engenics will conduct development research, and sponsoring firms will have the option of exploiting any patents in technology that Engenics chooses not to use exclusively. The Center of Biotechnology Research determines the allocation of research funding. By charter, it is enjoined to act in the best interests of the participating universities.

As alliances between business and higher education become more intimate, concern for their respective vital interests tends to increase. The elaborate mechanism described above is one possible way to insulate the various institutions from direct business involvement. However, as we will see, when industry and higher education enter into joint business ventures, this is far more difficult to do.

2. Joint Business Ventures. Aside from a university's traditional investment portfolio, there are several kinds of relationships between industry and academia that might be considered joint business ventures. One of these new mechanisms is the creation by a university of a venture-capital arm. The University of Rochester has become the first American university to undertake this option. University Ventures Incorporated (UVI) was formed as its subsidiary and controls $67 million of the University's $491 million endowment. Another vehicle by which universities can enter into business relationships is the assistance they give to entrepreneurial faculty wishing to start new companies. This is done not only to enhance the likelihood of the company's success but also to retain entrepreneurial faculty and not lose them to the business world. The University of Pennsylvania, for example, helps launch new companies through the University's City Science Center. The Center houses 63 small companies developing various technologies and provides them access to University research resources, inexpensive accounting systems, printing and contract negotiating services, and consultation.

Perhaps the most controversial of such commercial partnerships is a university's ownership, fully or in part, of a business concern. A widely known example is Harvard University's controversial proposal to establish a genetic engineering firm in which it would retain a share of equity. Following intense campus debate and a good deal of national and international press, Harvard rejected the proposal. Commenting on both the temptations and the hazards of such a partnership, Harvard president Derek Bok observed that the idea "seemed all but irresistible when Harvard officials first heard about the prospect of going into business with some of the University's ablest biochemists. . . . Harvard was being offered 10 percent of the stock of the new company at no cost to the institution. University presidents are not accustomed to turn their backs on offers of this kind. Even so, as my colleagues and I thought more about the matter, we slowly came to realize that our pathway to riches would be marked by every kind of snare and pitfall" (1982, p. 160).

Although widely publicized, Harvard's recent proposal was not the first. The MIT Development Foundation Incorporated was formed in 1972 to serve as a broker between developments at the institution and the interests of entrepreneurs wishing to establish companies based on promising MIT research. However, the Foundation was abolished in 1977 due to problems in creating viable enterprises, and its experience with conflicts of interest. While Harvard and Stanford have decided not to go this route, Washington University in St. Louis is using its funds to establish business enterprises. Washington University Technology Associates (WUTA) is an off-campus facility that utilizes faculty members to consult with private companies. WUTA employs a small staff that are not University faculty and runs the company like a business enterprise, with stock being held by the University.

In an attempt to circumvent conflicts of interest, universities are contemplating investment buffers in much the same way that Stanford University and the University of California consider the Center for Biotechnology Research to be a buffer. One idea is to establish an investment pool comprising many universities and managed by an independent group of investors. Another kind of investment buffer would be a business concern functioning much like a holding company.

It is uncertain which of the several mechanisms we have discussed will in the end be more appropriate for joint ventures. Nonetheless, the impetus to establish them is clear: universities wish to capitalize on the economic opportunities presented by new industries evolving out of their research. In spite of its many dangers, the prospect is inviting precisely because such joint ventures may increase not only the university's financial resources but perhaps its intellectual assets as well. Zinser's typology surveys the broad spectrum of possible partnerships between industry and higher education. We should note, however, that this model concerns basic types of partnerships and that actual arrangements may at times draw from several of these categories. Moreover, there is at almost every educational institution a layering of various kinds of partnerships. Philanthropy, faculty consulting, courses for hire, affiliate programs, and research agreements can all be underway simultaneously. Each can reinforce the other and in turn provide the basis for future agreements and alliances. We might also note that a single program can have different aspects. The Robotics Institute at Carnegie-Mellon University is a case in point. Westinghouse, Digital Equipment Corporation, and the Office of Naval Research are its primary sponsors. However, additional support is provided by 17 companies that have joined an affiliates program. It is in the context of this Institute that Carnegie-Mellon and Westinghouse developed specific agreements on robotics research.

The importance of a typology such as the one developed by Zinser lies not in any prescriptive use it might have but in its descriptive power. It enables us to gain a sense of the rich and diverse spectrum of current possibilities and to understand where new and creative arrangements might fit in. Because the needs of institutions vary, colleges will find certain arrangements more suitable than others. Community colleges may have greater interest in arrangements discussed early in the typology, while major research universities might be more interested in those discussed in later portions. Various corporations likewise will have different needs and interests. However, we believe that nearly any kind of institution and corporation could utilize a broad range of these possible partnerships, given the appropriate circumstances and an interested partner. Even though each partnership is a unique form of collaboration, our acquaintance with the full range of possibilities makes it easier to tailor arrangements to specific needs.

The Dynamics of Partnerships

The Central Importance of Attitude

When viewed from a distance or when reported in the press, partnership arrangements seem at times like a tangle of so many contractual clauses. After speaking with the partners themselves, however, one comes away with a very different impression. More important than the fine print is the attitude that partners bring to the alliance. Essential to effective collaboration is a climate that encourages an unhindered flow of new ideas, a willingnenss to confront differences as they arise, and a desire to arrive at solutions in spite of the obstacles that may present themselves. The broad range of partnerships that we have outlined above should not be taken as the real heart of the matter. While it is exceedingly helpful to gain some acquaintance with the anatomy of previous agreements, it does not give us an accurate perception of the flesh and blood of a partnership. Hence the importance of discussing its dynamics.

Based on his extensive survey of barriers to successful university-industry relationships, Donald Fowler concludes that "there are no overwhelmingly important problems, issues, or impediments that bar more and better relationships. In fact, the number and type of recently announced arrangements suggest that, given the necessary mutual incentives to do so, most relationships are in fact doable." Commenting on Carnegie-Mellon University's alliance with Westinghouse, Richard Van Horn emphasizes that "if you are willing to approach partnerships with the idea that you want to find solutions, then they invariably have great benefits. Our experience has been that it is very easy to find solutions if that is your goal. This can be done without compromising the principles important to universities."

While most partners will agree with Lord Macaulay that "men are never so likely to settle a question rightly as when they discuss it freely," they also find that this path can be strewn with obstacles.

For example, some difficult moments led up to the important and seminal Pajaro Dunes Conference, held in California in March 1982. Faculty from different sectors of the academic community aired so many grievances that it was difficult to get to issues of substance. "I suspect," says Robert Rosenzweig, "that something like this has characterized a number of meetings in universities across the country. Real issues existed, and they seemed to be growing in number as new contracts were announced in the press. There seemed to be little excuse for failing to consider these issues, for not defining them, assessing their importance, and considering how best to deal with them. That, in substance, constituted the agenda of the Pajaro Dunes Conference."

The shuttle diplomacy of a third-party broker can be no less difficult. Pat Hill Hubbard recalls the time when she was asked to head a task force. Its charge was to identify for education the subjects that industry needed to have taught. "I met with representatives from 10 companies for some six months," says Hubbard. "After incredible haggling and much gray hair, we produced a course of study that would take a community-college student six years to complete. To bring the parties in contact with reality, I decided that we needed to bring in community-college professors. This is when the blood really began to flow." Hubbard finally decided to do two things. One was to hold the meetings after work and supply a copious quantity of wine. The second was to separate the people into pairs, one from industry and one from higher education. "This way," explains Hubbard, "I thought there was at least a fifty-fifty chance of their coming to an agreement. What happened, of course, was that the pairs began to argue with one another. This gave me great insight into the fact that the debate does not really pit industry against education. At its heart is simply an age-old communication problem among people. Nevertheless, we did perservere and produce a profitable document."

Successful alliances are not forged by totally erasing the differences of opinion that both Rosenzweig and Hubbard describe. Rather, partnerships cohere by making these differences work to the mutual advantage of both parties. Although some common understanding is essential at the outset, and basic ground rules do need to be in place, partners should not defer collaboration until each and every issue is settled. As James Alleman rightly observes, "The point is not to resolve the difficulties first and then engage in cooperation. I think there is a lot more payoff to engage in the cooperative endeavor first, to stumble and bump into each other, and even fall all over the place. We need to work out our differences as we go along." Some initial experience will allow both parties to develop a more coherent framework for their alliance and to establish specific decision rules that will ensure its continued success.

Utilizing different perspectives effectively will bring a partnership into focus and contribute to its success. Differences, in short, need not become difficulties. As Roy Gavert of Westinghouse comments, "We have heard how business is nearsighted and has its feet mired in pay dirt while academia has its head in nebulous clouds. Frankly, we were in search of visionaries. We needed people who could think long term. We were not interested in just making incremental improvements in robotics technology; we wanted to leap-frog the entire competition." Gavert recalls how in the early days of the agreement with Carnegie-Mellon University there were some doubts about the wisdom of the marriage. University researchers started talking about such things as robots in outer space and artificial intelligence. Westinghouse, on the other hand, was initially more interested in automating mundane industrial operations such as soldering, welding, and inspection. But in the course of these discussions, Carnegie-Mellon University stimulated the interest of Westinghouse engineers in artificial intelligence and the potential of robots equipped with vision. In turn, Carnegie-Mellon became intellectually challenged by the problem of building a robot hand that could lift a hot billet without melting. When properly directed and utilized, cultural differences such as these can actually strengthen an alliance.

The Climate Conducive to Partnerships

Although good will and a positive attitude are indispensable, they are themselves not sufficient to guarantee a successful alliance. The willingness of each partner needs to be reinforced by an environment supportive of their alliance. Political and economic factors are, of course, critical ingredients in such a climate. However, they often lie beyond the immediate control of college administrators and company executives. While leaders in the educational and business community can assist in improving political and economic conditions, we will focus our attention chiefly on those environmental factors more directly under their influence.

As a first but nevertheless crucial step, leaders in higher education and industry must recognize that they do indeed exist within a common environment. Moreover, their different perspectives on that environment can be very useful to each other. Exchanging information on a regular basis will contribute to an awareness of these common interests and concerns. Moreover, it often facilitates the initiation of actual partnerships. Among the several mechanisms that Nanette Levinson finds particularly useful are industry liaison programs and symposia for industry representatives within a specific department or a general sector of the university. In addition to the exchange of information, the movement of personnel between organizations contributes in very important ways to a conducive environment. This can be accomplished through exchanges among professional and administrative personnel, sabbatical arrangements in the partner's organization or institution, and a well-developed continuing-education program.

The clin[illegible] for partnerships can also be improved by convening special meetings for representatives from industry and higher education. Levinson cautions, however, that the effectiveness of such meetings has to do not only with their specific agenda but with the kind of personnel invited. For example, it might be perfectly reasonable and effective to invite a vice-president for research. However, if such a selection is made purely for protocol reasons, the meeting may lose much of its effectiveness. In many instances, individual researchers need to share information with their counterparts in industry or higher education. Expanding such a meeting to an off-campus retreat, held perhaps once a year, can assist in improving regular communication between the business and academic communities. However, questions of format and location aside, these meetings can effectively promote an awareness of resources and opportunities. Commenting on the substantial effect that a broad range of such activities can have, Levinson observes that "the trust and history of collaboration that develops through these mechanisms provide a very fertile climate for initiating arrangements between industries and universities, and give them an excellent chance to work."

The sum of various factors and mechanisms that facilitate partnerships may be referred to as a network, that intangible but ever so important web of contacts and resources. The existence of such a network between the business and academic communities gives them a substantial head start toward developing formal alliances. Likewise, its absence presents a very real liability.

Establishing and maintaining a network are important activities not to be relegated a low priority. "At Cuyahoga Community College," says Nolen Ellison, "networking is a critical part of our planning in the job training and retraining area. For example, we developed a detailed inventory of organizations that can be classified as actual or potential resource providers, competitors, partners, or legitimizers whose support is important. We take such an inventory into account when choosing strategic targets or when fashioning implementation strategies."

In the absence of close alliances between industry and higher education, an informal network among business executives and educators can lay the groundwork for such alliances. As Ted Mulford is quick to point out, the presence of such a network was instrumental in establishing an engineering school at SUNY-Binghamton. An ongoing series of breakfast discussion meetings between business leaders and SUNY officials, and the existence of a high-technology council representing area firms, provided opportunities for frequent communication that made it possible to move so quickly and effectively on the engineering-school proposal.

When a city or region initiates an effort to attract high-technology firms, it soon discovers not only the importance of networking but also the extent to which this web of contacts and resources already exists. All too often, leaders from government, education, and business find that no such network is in place. As a consequence, one of their first steps must necessarily involve establishing and nurturing these ties. The city of Chicago, for example, established the Economic Development Commission to study the possibilities of attracting high-technology industries to the area. The Commission was successful in identifying the particular fields in which Chicago has existing or potential strengths. It also noted, however, the absence of an informal network between the high-technology and educational communities and emphasized that this is a serious impediment. Nonetheless, the joint activity of business executives and educators on the Commission contributed to the building of this network. An informal network of communication is a prerequisite for formal partnerships in the sense that it fosters the goodwill and understanding so necessary for initiating actual negotiations and guaranteeing their success.

The Evolution of Partnerships

Partnerships between industry and higher education do not happen by themselves nor can they be created on command. More important than instituting work plans, adhering to schedules, and organizing a series of pro forma conferences is understanding the evolution of partnerships and the ways they can be nurtured. A National Science Foundation report eloquently describes the subtleties involved in fostering these alliances: "The process of establishing university-industry interactions is not linear; it is circular, iterative, and sometimes discontinuous. It is not a mere mechanical matching of needs and capabilities followed by a definition of objectives and a working plan and schedule. It is, more importantly, an exercise in mutuality where understanding is more important than contracting; where personal contacts outweigh administrative mechanisms; and where ostensible purposes shelter undefined, and even more valuable priorities. In short, the process of exchange in university-industry research cooperation is much like the scientific enterprise itself—and where it is most successful it is most like the community from which it springs" (1982, p. 23).

The evolution of partnerships in time likewise entails subtle interactions that may not be immediately apparent. A history of trust and prior collaboration can generally be established through various channels. While it is true that the majority of partnerships are initiated by universities, they often build on prior contacts that originate in industry, such as consulting agreements. What emerges on closer scrutiny is a series of relationships with many stages. These include prior personal contacts, consulting relationships, current or prior research relationships, and contact with graduate students who may later enter the business community or become faculty. What we have, in short, is an ongoing cycle or loop wherein prior contact and collaboration provide fertile ground for future efforts. Additional factors that enter into this loop include corporate philanthropy, training programs, and continuing education.

A history of trust, communication, and prior collaboration is essential to partnerships that develop from the bottom up. Longstanding ties among scientists and researchers provide the necessary catalyst for this kind of evolution. However, even when partnerships are initiated from the top down through the leadership of a highly placed individual, their success often depends upon an established and effective network among scientists. The engineering school at SUNY-Binghamton is a case in point. The initiative for creating the school did indeed come from highly placed business leaders. Nonetheless, the success of their efforts would have been less certain had there not been very close and regular communication between the university and a broad cross section of the business and industrial community.

It is important, however, that contacts between industry and higher education be spared the ups and downs of typical organizational life cycles. An educational institution tends to have considerable interest in developing ties and working out cooperative arrangements with industry when it is establishing a new professional school or when there is insufficient enrollment or funds for existing activities and programs. However, as programs prosper, the incentives for industry cooperation diminish. Faculty become concerned with peer recognition for the quality of their research and the accomplishments of their graduate students. Only after a program is mature and its prestige assured is it likely to reexplore the possibilities of industry cooperation. Likewise, a corporation's interest in partnerships with educational institutions can wax and wane according to economic conditions, the development and growth of the company, its financial condition, and its market position with respect to competing firms. Both university presidents and industry executives need to guard against these natural, life-cycle tendencies to ensure that partnerships enjoy continued support. One cannot expect to have an effective partnership in a time of need if one does not cultivate it for the mutual, long-term benefit of both parties.

The Management Environment

UNDERSTANDING THE DYNAMICS of a partnership represents the first but nonetheless essential step toward fostering an alliance. If we are to translate these dynamics into actual collaboration, we must address three basic issues: (1) assessing needs and matching resources, (2) the role of management, and (3) organizational structures.

Assessing Needs and Matching Resources

Perhaps the most critical factor in establishing a successful partnership is an accurate assessment of needs. The balance of trade between higher education and industry is rarely even. To adequately evaluate this dynamic exchange, and the benefits and risks that accompany it, requires a very clear-headed and realistic assessment of needs and capabilities. Nanette Levinson describes this as becoming aware of opportunities to tap or acquire new resources that meet specific needs. "Nothing is going to happen," she observes, "unless you identify where those resources are."

This assessment of needs and capabilities is all the more critical because some observers find that "'high tech' is looking more and more like the latest development fad to hit the streets of America" (Gurwitz 1982, p. 32). Some development schemes do have a less than successful history. In the 1960s, cities promoted the downtown pedestrian mall. In the 1970s, they turned to a service-sector strategy designed to attract insurance companies and large conventions. The shift to high technology, however, is far more fundamental than many realize. It represents a profound structural change in our economy and society. This is all the more reason to encourage strategic planning and a careful evaluation of requirements and opportunities. A misplaced enthusiasm for popular solutions might easily crowd out innovative ideas for the regional development of high technology that spring from actual local needs and resources.

Gordon Voss observes that it is no easy matter to study the needs and resources of a particular area when constituents clamor for a high-tech "quick fix." "Political crisis and resulting decisions don't lend themselves to reasoned pathways. Communities desperate to rebuild their economies as rapidly as possible may not take the best road." Voss cites as an example the city of Duluth, an area particularly hard hit by the recent recession. The city is slowly eroding and aging because of the shift from a capital-based to a service-based economy. Its population has dropped 20 percent in recent years, senior citizens make up 25 percent of the population base, and unemployment runs at about 20 percent. Community leaders are looking to high technology as one of the most likely ways to rejuvenate their city, and they are petitioning the state for help in this effort. Their proposals include augmenting existing industrial technology programs at the University of Minnesota—Duluth, creating a new four-year engineering school there, and transferring the minerals-engineering program from Minneapolis to Duluth.

Voss, however, expresses concern that "the crisis nature of the problem may prompt hasty planning and an unwise use of resources. It is not immediately clear in the case of Duluth whether high tech should receive higher priority than tourism development, or even whether the city would derive the greatest cost-effectiveness by building on its existing programs or starting new ones. What is clear is that some effort should be expended to order priorities, identify potential markets, and evaluate the probable success of reaching those markets. State legislators must prepare themselves to resist forces requiring immediate action until they can do some preliminary planning. Due to the crisis nature of politics, this is not an unusual pitfall." Although colleges and corporations face somewhat different pressures, educators and executives will recognize in this example an all too familiar problem.

When conducting needs-assessment studies for a variety of educational institutions, NCHEMS Management Services has found that enlisting widespread support and participation contributes to the study's effectiveness. For example, the decision to assess the educational needs of local industries is more appropriate if made jointly by top management at the educational institutions involved and at local industries, with the cooperation and support of the local chamber of commerce or industry group. Moreover, experience suggests that local legislators often appreciate being apprised of such a study. Their support often becomes critical if state resources are needed to implement the report's recommendations.

The first task is to assess the current academic and research programs in the immediate geographic area that are relevant to the industries being studied and to understand how current educational resources are being used. NCHEMS has found it particularly important to differentiate needs according to specific types of industry. This can be done by employing Standard Industrial Classification (SIC) codes. These codes enable one to lea: n rather quickly what classes of industry are within an institution's service area. These industries presumably have the same general needs for certain kinds of programs and services. The next step is to assess the magnitude of these needs, both now and in the future. Having determined industry's requirements, one can then reassess the educational services provided by a local college or university. This process of matching needs with resources often indicates how an educational institution might better meet existing needs, or what new programs it might develop to attract and support high-technology industry.

Being willing to assess and respond to needs can result in serendipitous outcomes for a number of parties. George Baughman of Ohio State University recalls the Columbus Chamber of Commerce having been told that there were only seven high-tech companies in the city. However, when Ohio State put together a high-tech directory for the chamber of commerce, they found that the important and rapidly growing business sector that services high-tech companies had been ignored. A greater awareness of the kinds of industries operating in their community allowed the chamber to better understand and meet their needs. Providing another example, Baughman describes how a pharmaceutical house in Columbus approached his office about the possibility of establishing a pharmaceutical and toxological institute for helping medium-sized firms with drug testing. Baughman agreed to study the resources that Ohio State might have in this area. To his surprise, he discovered over 40 different departments that were engaged in research related to the pharmaceutical industry. "It soon became clear," adds Baughman, "that our biggest headache would be to find a conference room large enough to hold all of our potential partners." It also became apparent that the 40 different departments would benefit by closer collaboration and knowledge of what the others were doing, as would the individual companies with whom they were working.

In an effort to summarize his experience, Baughman developed a chart that describes the process of matching needs and resources (see table 6). The catalog of cooperative programs included in this chart follows that outlined by Neal H. Brodsky, Harold G. Kaufman, and John D. Tooker (1980) in *University/Industry Cooperation*. The catalog is particularly useful because it distinguishes between collaborative ventures and mechanisms for knowledge transfer, and also indicates which of these are long-term or short-term endeavors.

While business and industry press educational institutions for new programs that will meet their needs and those of their employees, legislators and taxpayers seldom appropriate more funds than are required to maintain current programs. Institutions are thus faced with a very difficult problem: How can they respond to the educational needs of local industries and their employees, contribute to the economic development of their region, maintain their current mission and role, and yet do so with no additional resources? Needs-assessment studies can help institutions and industries identify and focus on higher-order needs. In turn, these studies can enable them to develop common strategies for meeting these requirements. Understanding one's own environment and that of one's partner represents a crucial step in the strategic-planning process that will better match needs with resources and help guarantee the partnership's success.

Table 6

University Cooperation with Business, Industry, and Government
A Matrix of Possibilities

Resources → **Possible Cooperative Programs** ← **Needs**

Resources

University Resources

- Environment Conducive to Research and Learning
- Faculty
- Students
- Alumni
- Facilities, Equipment, Land
- Knowledge Services
- R&D Capacity
- Current Centers and Institutes

Business, Industry, and Government Resources

- Real World Problems
- Financial Resources
- Personnel
- Products/Services
- Facilities/Equipment

Possible Cooperative Programs

Collaborative Mechanisms
- On-going mode:
  - Institutes
  - Jointly Owned/ Operated Labs
  - Research Consortia
- Time-Limited mode:
  - Contracted Research/ Instruction
  - Cooperative Research/ Instruction

Knowledge Transfer Mechanisms
- On-going mode:
  - Liaison Programs
  - Technology Education
  - Continuing Education
  - Co-op Study Programs
  - Innovation Centers
  - Research Parks
- Time-Limited mode:
  - Consulting Contracts
  - Personnel Exchange
  - Information Exchange (seminars, publications)

Needs

Industry Needs

- New Products and Processes through R&D
- Trained Personnel
- Professional Development
- Strategic Information
- Access to Specialized Facilities and Equipment
- Professional Consulting
- Joint Venture Partners
- Development of New Markets

University Needs

- Opportunities to help solve real world problems
- Financial support for institution, faculty, and students
- Specialized equipment and facilities
- Joint Venture Partners

SOURCE: George Baughman, "Industry/University/Government Cooperation at Ohio State University," paper presented at the 1983 NCHEMS National Assembly, Denver, Colo., 9-11 February 1983.

The Role of Management

In order to capitalize on the opportunities that a needs-assessment study is likely to uncover, the college or corporation needs the active interest of a highly placed individual who can champion a collaborative arrangement. It is most desirable, of course, for this champion to be the university president or the chief executive officer of the company. Without active support from the top, the initiatives of middle management or faculty have little hope of succeeding. Strong leadership of this sort is particularly important for smaller firms and educational institutions that are not highly visible or that do not have a history of well-known partnerships. The value of having a highly placed champion derives not only from the need to deal effectively with outside parties but from the need to provide leadership within one's own organization.

Championing the cause, however, is not enough. Educators and executives must know how to translate their strategic vision of the partnership into concrete activities. Each must know how to manage the people involved, obtain the resources required, deal effectively with organizational policies, and know how and when to change those policies that hinder rather than foster innovative collaboration. If managing people in one's own organization is no easy task, coordinating different organizational cultures can present yet further challenges. Encouraging researchers and managers from industry and educational institutions to work together often requires an extra modicum of patience and a willingness to negotiate. The key members of a partnership team can often be those who are, by nature, independent and single purposed. The success of an alliance can often depend on tapping their creativity and initiative to the partnership's benefit. Moreover, the expectations of the parties involved can differ sharply. Researchers, for example, often have fixed opinions about the proper pace of research and the appropriate time for disseminating results. Corporate sponsors, however, usually operate in a much shorter time frame. This difference in perspective and expectation must be discussed and negotiated at the very outset of the project.

The actual or perceived needs of various individuals must likewise be acknowledged. For example, the space required by Carnegie-Mellon University's Robotics Institute aggravated an already critical shortage of that resource. This resulted in some degree of resentment on the part of other faculty and departments. The champion must be willing to understand how other parties are affected by the partnership and negotiate with them. Promoting a partnership also entails, then, a willingness to listen and learn and a capacity to extinguish the internal brush fires that may occasionally erupt.

Different temporal perspectives can also present significant problems for those engaged in a partnership. When changes are required in products, marketing, and personnel, companies make rapid decisions and implement them quickly. They are often unable to understand the slow pace of change that typifies higher education. Representatives from industry and higher education must discuss the need to balance short-term and long-term efforts. One challenge for corporate executives lies in protecting long-range endeavors from the immediate exigencies of the business climate. They will be under considerable pressure to justify the company's investment of time, effort, and funds in this partnership. Therefore, they will need some early successes to demonstrate the worth of the company's investment. On the other hand, they should be careful not to jeopardize the long-term benefits of a research project in their search for short-term results.

The president of a research university can help administrators and faculty understand that some short-range projects will be needed to balance long-range research goals. As in all negotiations, the president may find it necessary to articulate the needs of the corporation when talking to those within the institution, and to champion the university's perspective when negotiating with business. When dealing with an industrial counterpart, the president must try to protect and defend the longer time frame by reminding the executive that an advantage educational institutions provide is a stable environment within which long-term research can be pursued. These different temporal perspectives can be managed if the parties are willing to talk about them, explore alternatives, and if necessary, make compromises. Frank communication of specific concerns can often contribute to a well-designed project that will meet the needs of both parties.

Managing the partnership between industry and higher education requires not only diplomatic skill but a deep commitment to the strategic importance of alliances. Whether in the corporate boardroom or on campus, administrators must also develop policies and motivate people in such a way that their cause becomes a reality. It may be beneficial, and often necessary, that they demonstrate their own personal commitment to the project. David Saxon illustrates the influence that highly placed champions can exert by recounting one episode in the formation of Stanford's Center for Integrated Systems. The board of directors of one of the 17 corporations involved refused to authorize the required investment. In order to make the company listen, a very small group of senior executives within the firm put in their own money instead. Needless to say, the board sat up and took note; they carefully reconsidered the merits of the Center, and decided to enter into this collaborative arrangement.

Championing a partnership entails, then, more than simply believing in the cause. It also involves convincing others within one's own organization and a willingness and ability to negotiate with outside parties. Bringing a partnership to life requires a rare combination of vision, fortitude, and patience. One must be adept at managing people, marshalling resources, handling internal politics, and evaluating organizational policies. The job description involves, in short, knowing how to use existing personnel and structures effectively and appropriately, knowing when and how to change or shift personnel and organizational structures, and the near-saintly virtue of distinguishing between the two. Recognizing the differences that separate their respective organizational cultures, university presidents or company executives must present their organization's needs effectively, yet help their own organization understand the other party's requirements. However, providing leadership and demonstrating commitment is frequently not enough. In order to translate a cause into a working reality, one also must be adept at straddling organizational boundaries.

Organizational Structures

Although individual efforts play a significant if not crucial role in fostering partnerships between industry and higher education, these individuals nevertheless live in organizations, and their efforts must be channeled through organizational structures. While these structures can impede an alliance, they are also the necessary abutments that anchor our efforts to bridge institutional gaps. Developing linkages on an organizational level is perhaps the greatest challenge to the management of partnerships. As potential partners quickly discover, there is rarely a bureaucratic structure in place to handle what they wish to accomplish. Consequently, partners often experience some degree of bureacratic alienation. This situation can be remedied if both parties encourage and undergird the shuttling of ideas, proposals, and research results between higher education and industry.

Bridging the gap between organizations entails the development of some structural support. Just as a keystone supports an arch, so too some organizational entity or mechanism is required to support long-term connections between the business and academic communities. Nanette Levinson suggests that this can be accomplished by formalizing linkages that are both hierarchical and lateral in nature. Different levels within an organization must establish bridges between them and their respective partners. Moreover, they must also develop support from other units within their own organizations that will sanction these collaborative efforts.

In discussing the establishment of boundary-spanning structures, Elmira Johnson and Louis Tornatzky correctly argue that "university administrators and industry executives should probably devote as much time to the organizational design of the units involved in transactions as they do to the scientific and technological content of what is being exchanged" (1981, p. 51). There is, of course, no one design that can be used by every institution or industry to "bridge the gap." The design will vary with each institution and corporation, and it could be influenced by the following factors: whether the institution or company has had prior partnership experience and has some structures already in place; whether the president or chief executive officer has partnership experience to bring to the present situation; whether the partners want to engage in a short-term or a long-term arrangement; and what type of partnership arrangement is being explored, that is, its duration and degree of intimacy. In the case of training programs, for example, the organizational keystone may be the continuing-education office that can serve as a "broker" between the university and industry. In the case of a research project, the boundary-spanning unit may well be a newly created institute. In still other instances, the role may be filled by an independent foundation or third-party group. There are many instances, however, that do not require a highly formal organizational unit. A liaison office or liaison officer can frequently provide the "window" permitting ongoing communication and the structural mechanisms necessary to support that communication.

Spanning the boundary between organizations also provides avenues for better access. The relative stability of staff and faculty at higher-education institutions makes it easy for industry to gain entry to a college or university. Those in higher education, however, have a very difficult time knowing which corporate office or executive to contact. Becoming acquainted with the director of training, the director of employee relations, or the vice-president for research and technology helps little when in six months these executives may have moved on to new responsibilities or even new companies. Establishing structural ties between organizations can minimize the difficulties associated with their different temporal perspectives and with changes in personnel.

More important than the specific design of a boundary-spanning unit is our recognition that we must provide a structure for collaboration. Partnerships require a home. To operate effectively, the alliance must have a recognized niche in the academic and industrial communities. Failing this, it will invariably be perceived as a stepchild of some other unit. Homesteading a joint project can be a demanding and frustrating task; yet without a home, the project is likely to be shunted aside and forgotten.

The keystone in the arch connecting higher education and industry must not only be set in place but continually maintained. Even after the organizational unit is designated or developed, sustained efforts must be taken to ensure that this connection remains effective. Because partnership arrangements are departures from normal organizational structures, those engaged in a joint project are likely to be working outside of their organization's normal incentive system. Alliances may well require a review of that system to ensure that individual efforts on the partnership's behalf do not go unrecognized. In an academic environment, incentives and rewards take the form of promotion and tenure. If a faculty member's participation in a joint project with industry is not considered when the tenure decision is made, that person or other faculty are not likely to participate in such activities in the future. Incentives in the corporate world frequently have to do with status and upward mobility. A company's failure to reward participation in a joint project with an educational institution likewise inhibits the willingness of its engineers, scientists, and managers to work on these partnerships.

Maintaining the health of a boundary-spanning structure requires that resources be directed to it. If a partnership between industry and higher education has developed a home independent of two larger organizations, it may be in a position to attract its own funding and develop its own budgets. However, if the organizational unit acting as a "window" between industry and education is located in one or the other organization, then attracting sufficient resources can often be a problem. Funding might become a low priority for the parent organization and lie beyond the control of the partner organization. Guaranteeing adequate support to the unit administering the partnership is one of the primary duties of the executive responsible for championing the alliance. Moreover, we should think of resources not only in terms of research budgets, educational programs, and faculty salaries but also in terms of psychological support. Assistance must also be explicitly provided to those seemingly tangential personnel and programs whose work load has been affected by the alliance.

The organizational home of a partnership may require its own policies and procedures. When these are different from those of its parent organizations, confusion and some degree of conflict can result. To minimize this, the chief advocates of the partnership should regularly discuss these policy issues both among themselves and with their own organizations. When the organizational structures supporting collaboration need a distinct set of policies and procedures, it is equally important that their rationale and implementation be understood by all concerned.

Initial efforts to position a partnership with respect to larger organizational entities are themselves not sufficient. One must not only design an organizational structure for the partnership or designate a new role for existing structures, one must also ensure their continued visibility. To prevent the first flush of enthusiasm and support from fading away, ongoing promotion of the project is essential. Its results and successes must be communicated not only to one's partner in the collaboration, or to interested third parties, but also within one's own organization. This can often be accomplished by establishing an advisory board, whose function would be to advocate, evaluate, and otherwise monitor the health of the partnership.

The management of partnerships between higher education and industry is rather complex precisely because it involves different organizational structures, policies, even cultures. Contributing to this complexity is the fact that each partnership is necessarily a unique arrangement entailing rather specific management requirements. Nonetheless, the management of an alliance can be made more effective if its chief advocates are aware of the several important factors we have dicussed: an accurate assessment of n eds and a careful matching of resources; the role of manageme: [illegible] oioning the cause of the partnership, both to the other pai [illegible] vithin one's own organization; and the importance of adapting or creating structures that span organizational boundaries and thereby lend support to the partnership. Only when these larger management issues are well understood does an alliance have a reasonable chance of succeeding.

Negotiating and Managing the Contract

AS IN MARRIAGE, the knot that ties a partnersh. can quickly unravel if a long-term contract is based on temporary emotions and unexamined perceptions. Negotiations enable both parties to broach issues likely to present themselves during the course of their collaboration. If both parties enter these discussions with an open mind and do not become too territorial or protective early in their talks, new and innovative arrangements are possible, as are mutually satisfactory results. Because they address actual needs and resources, contractual agreements between a company and an institution are by their very nature quite specific. Nonetheless, we can discuss some of the general topics that ought to be raised during negotiations, the contractual resolutions that need to be achieved, and some of the general management issues that pertain to these agreements. During contractual negotiations both parties should reach agreement in the following areas:

1. The scope of the partnership and the respective roles of the participants
2. Intellectual property rights
3. Financial arrangements and their implications
4. The outcome of the project
5. Safeguards for the project

The Scope of the Partnership

The type of contract negotiated will largely depend on who the parties are and what they want to achieve through their collaboration. For this reason, interested parties should understand several important issues before negotiations begin: the number of parties involved, the type of work that will result, and the length of the contract.

If a corporation and an educational institution wish to develop, for example, a training module, the contract will more than likely specify a short-term relationship. The corporation will presumably be the contractor, and the educational institution the contractee. However, if they wish to develop a long-term relationship through, for example, a joint laboratory or institute, then their relationship is apt to be more collaborative and require substantial commitments from both parties. Clearly, the contract appropriate for the short-term development of a training module is not suitable for a long-term collaborative relationship. Moreover, an institution may engage in a partnership with several companies. In this instance, it is unlikely that short-term contractual work would be performed for all of them. Such arrangements tend to involve a considerable degree of knowledge transfer between and among the companies and the institution.

As these examples illustrate, a contract written for any of these arrangements will necessarily have a specific focus and intent. The variables encountered during the negotiating process are likely to be numerous: single-party contracts will vary from multiclient projects; contractual work may be easier to specify than the outcome of a long-term joint relationship; short-term, finite projects will require a different negotiating approach than long-term, research relationships. However, irrespective of the type of contract discussed, each of the parties involved must have resolved in its own mind the following two points: that they cannot compete with each other and win, and that each has something to gain from the collaboration.

Defining the role of each partner can have very broad and important implications, extending from rather general topics, such as with whom one should collaborate, to more detailed items specifically concerned with the operation of the project. Certain projects tend to be more appropriate for certain partners. Moreover, this appropriateness can change during the life of the project. Christine Bullen of MIT's Center for Information Systems Research provides an apt example. "Given the nature of our research in information systems, we were very cautious at the outset about approving vendors as sponsors. Although several vendors wanted to become sponsors, we felt that their participation might give the impression that they would have undue influence. It wasn't until we had 10 other sponsors that we let these vendors come on board. We also avoided consulting firms, because in most cases they are interested in other industry contacts more than they are in our own research."

There are generally more partners in a cooperative enterprise than one tends to realize. A party that may seem peripheral to the actual project may in fact prove to be not only interested in but vital to its success. For example, sometimes it is essential to enlist the direct or indirect support of a labor union. The blessings provided by such an interested yet perhaps outside party can help sanction and legitimize the alliance. The truly forgotten parties, however, tend to be those within one's own organization. An effective partnership must have something in it for everyone. This not only applies to the main players but extends to support personnel as well. Even though an administrative office may seem only remotely related to the enterprise, it should receive additional support if it will experience an increased work load due to the alliance.

Many of the problems associated with defining the roles of chief players can be mitigated, says Nanette Levinson, by defining the area of mutual interest in very neutral terms. Although it needs to be made clear what each party's role is, one runs the risk of becoming territorial when defining these roles too strictly or without an awareness of the other party's legitimate concerns.

Because partnerships often require structural change within an organization, one must be alert to the possibility that new roles may conflict with those already established. This may lead to what might usefully be termed as conflicts of commitment. While such conflicts are not in and of themselves financial, they do concern the way an individual's time, work, and responsibility are divided. As a result, ongoing duties and commitments may suffer. Conflicts of commitment may extend to those individuals working for or under a particular scientist or administrator, or they may include undue influence by the outside partner on an individual's work or research. As is the case with all such potential problems, they should be raised and openly discussed at the outset of negotiations and throughout the course of the partnership.

Intellectual Property Rights

Property rights have long been sacred; staking out an acre, however, is far easier than protecting an idea. While fences may make good neighbors, it is far less certain that they make good partners. The role of intellectual property rights in partnerships has generated a great deal of controversy, particularly in the press. University faculty are legitimately concerned about entering into collaborative arrangements that will jeopardize their academic freedom and their ability to pursue new ideas and carry out unfettered research. Industry executives, on the other hand, hesitate at paying for research and then not having adequate access to or ownership of its results. The future of the company and its market share may depend on having first or perhaps sole use of research carried out at an educational institution. The Pajaro Dunes Conference was but the first of several conferences that have attempted to sort out the principles that should govern contractual agreements in this area.

Summarizing the issues at stake, John Slaughter observes that "universities have a vested interest in academic freedom and the open exchange of ideas. Such an atmosphere is absolutely necessary for creative and productive research. At the same time, industry is legitimately concerned about protecting its rights to the results of the research it supports. Furthermore, all participants in cooperative ventures need to know who has the right to publish results and who gets patent rights and royalties." Because both sides may incur substantial risks if these issues are not openly discussed and clearly resolved, negotiations should specify conditions pertaining to publication rights, patent rights, and royalties. Partners should be cognizant of the trade-offs that might be involved. Undue protection of intellectual property rights can stifle innovation and violate academic freedom, while unrestrained communication can make it economically unfeasible, even hazardous, for a company to participate. Before partners build any walls, they should ask to know what they are walling in or walling out.

Although the conflict between publishing research results and protecting proprietary information looms as a classic and unresolvable opposition of vested interests, experience indicates that this question can most often be resolved in a mutually satisfactory manner. The university administrators that Donald Fowler surveyed were generally in favor of withholding the publication of research results until the industry was able to acquire the patents necessary to protect its investment. Moreover, approximately one-half of industry executives felt that patent protection should be the only reason for asking university faculty to withhold publication of proprietary research results. Fowler concludes from his survey that "a workable solution involving limited delaying of publication pending protection for patents is close at hand. Recently announced arrangements suggest that solutions along these lines are being widely adopted." A review period of up to 30 days is quite common. Nanette Levinson's research indicates that problems occur only "when the review period is unspecified or when it appears to be unduly long without good reason."

Industry is naturally inclined to want title to whatever inventions result from industry-sponsored research. If a university is willing to give the title to the industrial sponsor, there is little if any problem. While some agree to do this, the majority of institutions prefer not to allow an outright transfer. Nevertheless, there now appear to be many situations in which industrial sponsors are willing to accept nonexclusive licenses. "Lack of an exclusive license," says Fowler, "is often compensated for by the industrial sponsor's competitive position in its field and by the fact that it has immediate access to information that will take its competitors a number of months to duplicate."

Commenting on the policies of Carnegie-Mellon University, Richard Van Horn says that the institution tries to provide intellectual property rights to someone who really has an interest in developing them. These tend to be the industrial sponsors, who excel in this kind of activity. He emphasizes, however, that the University retains publication rights. "We have to be able to publish on any work that we do. But I don't see any great concern about delaying publication so that the sponsor can have some commercial protection. Professional journals delay publication much longer than any sponsor could."

A consensus is developing that intellectual property rights are a manageable issue. Although risks are present, most partners believe the difficulties are not insurmountable. Both higher education and industry are aware that important principles are at stake; those negotiating a partnership arrangement recognize that they must work diligently to arrive at mutually acceptable solutions. The many partnerships already in existence, however, attest to the fact that the issue is not the obstacle it was once thought to be.

Financial Arrangements and Their Implications

Once the scope of work is negotiated and an agreement is reached concerning intellectal property rights, it becomes necessary to determine what resources are required to make the partnership feasible.

To ensure success, future partnership arrangements should be predicated on the notion that not only individuals but organizations must work together. In the past, industry's research funding has tended to follow the pattern developed by the federal government: an individual researcher is provided with money to carry out a specific project. There is little understanding and in some cases outright resistence to the notion that the larger organization within which the faculty member or researcher works also needs support. As partnerships mature and stronger ties are instituted between universities and corporations, it is essential that arrangements address organizational needs and not merely the interests of individual professors, researchers, or executives.

Financial negotiations should address not only the direct costs of a project but also the indirect costs incurred by an entire organization when it accepts additional tasks and activities. The contract should also detail payment schedules and specify who will serve as fiscal agents of both parties. Financial compensation from industry is often tied to periodic review of the project, to the progress of scheduled research, or to the timely and efficient transfer of ideas or products. While some industries are perfectly willing to provide blank checks for research, most partnerships are based on some quid pro quo; payments are tied to the delivery of certain ideas or results.

Because financial arrangements differ greatly from partnership to partnership, it is difficult to comment on actual dollars-and-cents issues. However, just as important as financial arrangements is an awareness of the implications that they hold. Financial management concerns more than a budget; it entails managing the use of, and the access to, people and information.

In the case of periodic payments, financial arrangements often raise questions concerning the ongoing management of the partnership. Roy Gavert of Westinghouse, for example, recalls that "in working out the agreement with Carnegie-Mellon University, there were some differences of opinion regarding the management and funding of the program. A few of the researchers at the University wanted to receive all of the funding for the five-year program in one lump sum. For our mutual benefit, we felt we needed to demonstrate to management that we were on the right track. So we reached a compromise. We developed progress schedules and established clearly defined milestones. We agreed to pay CMU in monthly payments over the year equaling the total requested. Westinghouse reserved the right to modify payments or curtail funding if substantial progress was not being made. This approach also gave us the opportunity to test incremental hardware developments as soon as they became available."

In the case of consortia and affiliate programs, firms do not receive products or exclusive proprietary rights but, rather, advance notice of research. Hence, financial arrangements are tied to access: the manner and degree of interaction between the various parties, structural mechanisms for this interaction, lines of communication, and mechanisms for transferring research results and information.

By their very nature, partnerships between higher education and industry can create conflicts of interest, some of which may be financial in nature. Because business opportunities most often involve proprietary information, they may not mesh well with academic responsibilities. University research is predicated upon widespread dissemination, and teaching requires a free and open exchange of knowledge. Thus, it may prove to be an unrealistic burden on faculty to isolate their teaching and research interests from a sponsored research project, much less from their own financial involvement in the enterprise. While this possibility has received a good deal of comment, actual abuses have been rather limited. Nonetheless, the subtle demands of secrecy can have an undesirable cumulative effect. Effective management of a partnership and responsible negotiation of the contract require, therefore, that this issue be raised at the outset. An unwillingness to openly discuss the potential for conflicts of interest will engender precisely those conditions that lead to such conflicts.

When managed strategically, financial commitments become not only the end result of an agreement but a means of fostering additional support. Partnerships offer a unique and welcome opportunity to make the sum of financial commitments greater than their individual parts. This can be accomplished through such mechanisms as leveraging and matching grants. Moreover, partnerships have a way of generating what might be referred to as a "me too" effect. Robert Rosenzweig points to Stanford's Center for Integrated Circuits. "Why are there 17 corporations involved?" he asks. "I can tell you why the 17th came in: it was because the first 16 were already involved. The 16th came in because the first 15 had taken the initiative. While it is true that none of them will receive the specific proprietary advantage that they would get from a one-to-one relationship, it is also true that none of them can afford to stay out."

What makes partnerships not only possible but lucrative is that they allow companies and universities to derive advantage and avoid risks in ways that would not be possible were they acting alone. Effective management of a partnership agreement stresses this "exponential" effect and the financial returns and intellectual rewards that can be derived.

The Outcome of the Project

"Begin at the beginning . . . and go on till you come to the end: then stop." Lewis Carroll's advice notwithstanding, determining when a joint project has come to an end is no easy task. Researchers and administrators alike will have committed a great deal of time and effort to the endeavor. Consequently, they may be unwilling or find themselves unable to let go of it at the proper time. For this reason, a contract should clearly specify what will have been accomplished by the end of the project or what events will signal its conclusion. These may include the transfer of results from one party to another, the delivery of a training module to a certain number of people or for a certain period of time, or other circumstances that will indicate that a particular project has fulfilled its usefulness.

The contract should also stipulate those circumstances under which each party can cancel the agreement. The company should have every right to terminate the contract if the university does not perform satisfactorily or on schedule. Likewise, the university should have the right to cancel if the company does not pay, does not provide the necessary information, or otherwise does not meet its obligations. If a project is canceled midstream, it will be important to specify who is entitled to payment for what services, and what the disposition of the research results will be at that point in time.

Determining when duties and responsibilities will shift from one partner to the other in the course of a project can also prove difficult. One industry representative commented that, in theory, it sounds simple enough: university researchers develop and demonstrate new concepts, and industry engineers then test and debug their ideas on the factory floor. The process is complicated by researchers who want to see their idea through to its fruition. While this tendency can have its positive aspects, it can also have a serious impact on working relationships. For this reason, clear lines have to be drawn indicating when the various partners in the project should "pass the baton." One company may decide that the university researcher should develop an idea or work at a solution to a problem and then have company engineers implement it. Another company may be perfectly happy to have the researcher work on an initial problem, collaborate with company engineers on the further refinement of a solution, and assist them in its implementation. It remains for each party to negotiate the passing of the baton in light of the specific circumstances of their project, its time frame, and the preferences of those involved.

Safeguards for the Project

When negotiating the contract, it is advisable to consider some safeguards that will protect the project, assure that it continues in spite of changes in circumstances or personnel, and guarantee that it can respond to such changes. An advisory board can provide a useful mechanism for ensuring the proper, ongoing management of a partnership. Even though contract negotiations attempt to clarify as many issues as possible, the daily operation of a cooperative project invariably uncovers new problems or unforeseen circumstances that can cause small operational difficulties. An advisory board can troubleshoot these areas of disagreement or friction.

As a general rule, board members are drawn from both the university and industrial communities and may also include interested third parties. Regularly scheduled meetings help ensure the smooth functioning of the partnership. Commenting on its importance, Nanette Levinson observes that an advisory board can "maintain momentum and commitment on the part of the collaborating organizations and can also serve as an ongoing structure to enhance the transfer of ideas, especially at the administrative level."

Roy Gavert of Westinghouse illustrates the importance of an advisory board by relating an episode from his company's collaboration with Carnegie-Mellon University. "To manage our interface with Carnegie-Mellon University, we have established an advisory committee that meets once a month. The committee assesses the status of the research, approves future funding, and advises on the future direction of the research. We have found that this approach actually stimulates inventiveness. At one point in the program, for instance, we were not totally satisfied with the progress being made in the development of an automated inspection system, and so we stopped funding that particular part of the project. The University decided to continue the research and brought in a new researcher who had some fresh ideas. A new approach to the problem was found, and Westinghouse subsequently decided to reestablish funding for this particular project. Without this review process, an important part of the program would have been off track, and more importantly, a new approach may not have been discovered."

When working out the details of a contract, it is useful to recall that an agreement should extend beyond any one particular individual. Given the rapid turnover of personnel in the corporate sector, it is quite possible that those involved in negotiating the original contract may have moved on to other responsibilities, perhaps even other companies, during the life of the partnership. For this reason it is important to set into place contractual agreements that will enable the project to remain on an even keel, while at the same time allowing the partners to accommodate new circumstances. A contract should also specify the exact procedure for any further negotiations concerning changes and amendments. Moreover, it would be advisable to enumerate those specific areas where the parties are dependent on or independent of each other. For example, it might be appropriate to specify that a university have full power to select the means, manner, and method of performing certain functions without a company's immediate control or direction.

Rapid changes in the business environment, particularly in high technology, make it very apparent that gentlemen's agreements are not a useful way to proceed. Written agreements will be necessary to ensure that the original intent of the partnership is understood by all of those who come in contact with it. Such agreements protect the project from the pressures and influences that new people may try to exert on an ongoing relationship.

Alliances are as varied as the partners who engage in them. Without adequate insight into their structure, dynamics, and management, we can easily find these partnerships to be confusing. But if we understand their rationale and develop a strategic vision of the future, we will not find them without plan, purpose, or great promise. By structuring an alliance carefully, and managing it well throughout the period of collaboration, we can improve its performance and prevent unreasonable expectations that may lead to disenchantment. This in turn will encourage still others to "keep an eye out for partners."

"The future of partnerships greatly depends on our fostering the strategic perspective that allows each party to assess and appreciate the substantial rewards that alliances can provide. With this kind of realistic and forward-looking appraisal, both higher education and industry are likely to avoid the two extremes of unthinking enthusiasm for popular solutions and an unwillingness to consider new options."

Conclusion

Reviewing the Rationale for Partnerships

WITH THE INFORMATION SOCIETY more a reality than a future prospect, partnerships between higher education and industry become not only desirable but necessary. At the outset of this book, Lewis Thomas reminded us that "the urge to form partnerships, to link up in collaborative arrangements, is perhaps the oldest, strongest, and most fundamental force in nature." As we conclude, it should be apparent that alliances are also crucial to our social, educational, and technological evolution.

In chapter 1 we described many of the changes that have prompted the two worlds of higher education and industry toward closer collaboration. As an information society, we find ourselves relying to an increasing degree on knowledge-based, high-technology industries, while the familiar, capital-intensive industries that we have depended on in the past are fading. Moreover, high technology is an instrument of change that does not recognize national boundaries. It is born global and requires that we compete as never before in the world marketplace. No longer can we afford to direct our attention inward—to focus solely on the requirements of our sunset industries or to make only marginal changes to those past solutions that were adequate to a more isolated, national economy. We must instead look outward, recognize new forms of interdependence, and develop those partnerships that allow us to excel. The stakes are substantial precisely because high technology provides the foundation for so much of our social and economic life.

The symbiotic relationship between higher education and industry derives from the central importance of education in a knowledge-intensive society. This mutual dependence is likely to develop rather than diminish in the future. Preparing students and workers to be productive in a technological world by no means implies that higher-education institutions should turn themselves into job-training shops. On the contrary, it is exceedingly important that students receive not only a strong background in mathematics and science but also the liberal education and analytic training that will allow them to deal with the social and philosophical issues raised by high technology.

The alliances that we are proposing are not without precedent. The 1862 Morrill Act laid the foundation for cooperation between higher education, industry, and government. Their interaction since that time has provided a body of experience that demonstrates the usefulness of partnerships. The emergence of high technology requires, however, that we recognize the necessity of these alliances and develop new strategies for their implementation and better management.

In chapter 2 we described in considerable detail the actors involved in partnerships and the various needs and interests that prompt their collaboration. These needs should not be perceived as a wish list that details what one wants from the other. It is more important that we understand the basic prerequisites necessary for partnerships; these alliances themselves will assist higher education and industry to meet their needs. Colleges and universities do require additional support for their faculty and graduate students, and more resources for basic research, facilities, and equipment. Moreover, they must ensure that core programs are well maintained so that they can provide a broad education, not simply narrow training. Institutions will also need to develop new patterns of education and ensure that their organizational structures and policies will help foster partnerships with industry. These needs vary, of course, depending on the type of institution and its specific circumstances. The requirements of a major research university, for example, differ from those of a community college. Consequently, it is important that industry executives and government leaders recognize the differentiated needs of higher-education institutions.

Although business and industry are themselves quite diverse, they do have some very well-defined and essential needs. They require, first and foremost, a dependable source of well-educated graduates from which they can recruit their employees. Moreover, they need programs that will help professionals sharpen their skills and keep up with changing technology. Industry is also looking to higher education for new windows on research and a renaissance in innovation. They believe that partnerships with educational institutions may produce the creative spark they require. However, as is the case with colleges and universities, industry must ensure that its own organizational structure and policies will promote and not hinder the very alliances they seek to form.

Third parties can play a major supporting role in the effort of business and education to form partnerships. Trade and professional associations, regional and state associations, and brokering efforts on behalf of higher education can all help to focus the issues that draw colleges and corporations together. Often these associations can accomplish what no individual company or university can do: they can amass a sizable amount of financial support and target these funds at programs likely to meet the common needs of industry and higher education. Third parties can be effective shuttle diplomats because they are able to understand and present the actual needs of institutions and companies in a way that is credible and free of self-interest.

State and federal government can also do much to encourage partnership arrangements between higher education and industry. The establishment of high-tech councils by governors and mayors may be an important first step in encouraging the different parties to sit down and discuss how each can contribute to the economic development of their city, region, or state. State government can help provide incubators for new high-tech industries, offer economic incentives, and encourage the application of high tech to sunset industries. Likewise, the federal government can provide incentives, reduce obstacles, and increase resources to those agencies, like the National Science Foundation, that actively support partnership arrangements. While a coherent national policy on education and industrial development can assist these alliances, colleges and corporations are collaborating precisely because they believe there are benefits to be gained from such an arrangement, with or without a national policy in place.

When properly implemented and managed, partnerships between higher education and industry can be a strategic response to their circumstances and needs. In chapter 3 we surveyed the broad spectrum of possible arrangements. However, an acquaintance with the many forms that collaboration can take is itself not sufficient. Accordingly, we have emphasized the importance of attitude among those championing partnerships, discussed the kind of climate that will foster joint projects, and described the likely evolution of these alliances.

As Ben Lawrence, the President of NCHEMS, recently remarked to the National Council of Community College Business Officials, "The difference between Heaven and Hell is not the temperature, it's the management." This too can be the difference between a successful and a failed partnership. Because the development of high technology has in some respects acquired the characteristics of a fad, we have placed particular importance on a detailed assessment of needs and resources. Management must not merely champion popular solutions but ensure that partnerships actually tap these resources and meet these needs. When managing people and marshaling new resources, educators and executives must also be aware of the organizational environment in which partnerships function. Perhaps our greatest challenge lies in making our institutions adequate to the partnerships of the future. Well-formulated contracts can help guarantee the success of an alliance. Of more importance, however, is the willing and positive attitude that parties bring to these negotiations. Partnerships are not solutions that we can simply invoke; they are natural extensions of our mutual understanding and respect for each other's needs and interests.

A Summary of Benefits and Risks

ALLIANCES provide higher education and industry with new opportunities and substantial benefits; yet they are not without new risks and responsibilities. In this book we offer no easy guidelines, no pat solutions. Educational institutions and business enterprises must both establish their own policies by debating the benefits and risks that partnerships entail. With few, if any, absolutes, most issues emerge not as black or white but as matters of degree. Hence the most valued qualities in any prospective partner include a clear sense of mission, a good dose of common sense, and a generous capacity for mutual understanding. Just as the needs and interests of both communities vary, so will the process of forging alliances. Likewise, we should expect that partnerships will be as diverse and unique as the partners who enter into them. The best partners will be those that stress mutual benefits, are alert to possible risks, and accept the necessity of certain trade-offs. It may prove useful at this point to summarize these benefits and risks.

Benefits to Higher Education

- Partnerships can provide additional funding sources for faculty salaries, research, and educational programs. Further, income might also accrue from licensing and patent arrangements.
- Alliances can also offer technical and physical resources that are not otherwise available to the college or university. Industry can often provide access to state-of-the-art equipment, donate it, or help subsidize its purchase.
- Ongoing cooperation with industry can generate the resources a college or university needs to hire new faculty. Consulting possibilities or research grants from industry allow institutions to offer prospective faculty an attractive compensation package that includes benefits and opportunities.

- Involvement in a partnership can enhance an institution's curriculum. Alliances often afford faculty access to industry projects and may even furnish students with part-time or summer employment. This provides both faculty and students with important experience that could not be gained within the classroom.
- Cooperative arrangements can encourage industry professionals to participate in the educational programs of a college or university. This provides a welcome source of adjunct faculty, particularly in such areas as computer science and engineering. Moreover, it enriches not only an institution's curriculum but also the corporate environment.
- The support of business and industry in areas of scientific and engineering education can enable the college or university to maintain the health of core programs in the arts and humanities.
- Collaboration can increase awareness among faculty and administrators of industry's needs and resources. Moreover, it can improve their understanding of the larger environment that both higher education and industry share.

Risks to Higher Education

- Industry may exert undue influence on the cooperative program or on the nature and direction of future programs and research endeavors.
- Partnership arrangements could prove detrimental to the quality and nature of instruction. Sponsored projects may not provide an appropriate educational experience, and faculty members who receive substantial industrial support may not adequately attend to their teaching responsibilities.
- Conflicts of duty and commitment can arise due to new responsibilities. Likewise, the prospect of commercial gain can create financial conflicts of interest. Institutions and their faculty members will need to review partnerships in light of existing duties and financial arrangements.

- Because cooperation with business and industry often entails information that is proprietary in nature, intellectual freedom and the right to publish may be inhibited.
- Substantial industrial involvement on campus may unduly influence an institution's long-term educational mission. This in turn could affect programs in the arts and humanities and skew the internal allocation of resources.

Benefits to Industry

- Partnerships with colleges and universities can ensure industry of a skilled and adequately trained work force. Moreover, they can allow companies to orient students to the industrial environment, cut their recruiting costs, and employ workers already thoroughly familiar with their operation.
- Collaboration with university scientists can afford companies new windows on research. Their joint efforts can smooth technology transfer and enhance the innovation process.
- Alliances increase industry's ability to influence research directions and educational programs. Moreover, they enable companies to offer feedback to universities on their particular research and training needs.
- Current tax laws permit a company to contribute up to 5 percent of its pretax profit to higher education, with substantial tax deductions.
- Partnerships can increase industry's understanding of higher education and its diverse needs and resources. Most chief executive officers may have had little personal contact with academia since their own university experience many years ago.
- One benefit not to be overlooked is that collaboration with a university can enhance a firm's image. Corporations that enter into partnerships with local educational institutions can derive considerable public-relations mileage from such a relationship.

Risks to Industry

- Cooperation with educational institutions can diminish the control that corporations have over proprietary information. However, given the high personnel turnover in many industrial sectors, the loss of proprietary information is not a risk unique to educational partnerships.
- Sponsored research performed at an educational institution may lack particular relevance to a company, and instructional programs may not meet a firm's specific needs. These risks can often be controlled through appropriate oversight and regular communication between both parties.

When detailing the possible benefits and risks that can accrue from partnerships, we should not forget that some of the most important advantages are often the least tangible. Considerable benefit can occur, for example, at the organizational level. Colleges and universities have always been knowledge-intensive industries. For that reason they should have much in common with new knowledge-based, high-tech industries. Both organizations have much to learn from each other. Educators can benefit from those in industry who have been involved in strategic planning, environmental scanning, the development of new organizational forms to support emerging technology, and the creation of new incentives and rewards for those who work within such organizations. Likewise, managers in industry have much to learn about creating an organizational climate that encourages research and free inquiry, provides incentives and rewards fostering human-resource development and loyalty to organizational goals, and generates a cohesive community of scholars and learners. We might add that the most important yet least tangible benefit to be derived from partnerships is increased understanding. The more we know about the workings and dynamics of another organizational culture, the better able we shall be to develop mutually beneficial collaboration.

The most dangerous risks, in turn, are those that we seldom recognize. Maintenance of the status quo, an unwillingness to look for innovative solutions, and the tendency to view the future as a simple extension of the past are far more hazardous than any of the risks mentioned above.

The Future of Partnerships

PARTNERSHIPS between higher education and industry may require some transformation in institutional structures. In other words, alliances can create new forms and challenge the existence of old ones. If we are to manage and utilize these partnerships effectively, we must ensure that these changes in structure follow from our strategic vision of the future. We cannot afford to have our strategy held hostage by the outmoded structures that may dominate many of our educational and industrial organizations. On the other hand, we cannot afford to have our strategy follow from structures that, however modish or fashionable they may be, are not appropriate to the mission of a college or corporation. The future of partnerships greatly depends on our fostering the strategic perspective that allows each party to assess and appreciate the substantial rewards that alliances can provide. With this kind of realistic and forward-looking appraisal, both higher education and industry are likely to avoid the two extremes of unthinking enthusiasm for popular solutions and an unwillingness to consider new options.

It has been said that "nothing is more damaging to a new truth than an old error." Likewise, the chief hindrance to new alliances is our old frame of mind—preconceptions, outmoded strategies, and ineffective organizational practices. Inevitably, these perspectives have become crystallized in the structure of our institutions and corporations, the very arena in which we must forge our new alliance. This book has sought to help both higher education and industry uncover the many subtle, unconscious limitations on what each thinks is possible. As the two worlds of higher education and industry draw closer together, it is important that each recognize the strategic role that the other plays in its further evolution.

To ensure future partnerships we must guarantee that our institutions and corporations will foster these alliances. As partnerships between industry and higher education mature, ties between the two communities will move beyond individual contacts and initiatives and become established on an organizational level. Stronger ties will help foster far more than the sporadic collaboration characteristic of partnerships today; regular and close communication will provide a permanent link between both groups. We can best guarantee the future of alliances by stressing these organizational linkages and by looking beyond isolated projects to ongoing, innovative partnerships.

A sustained partnership insulated from the vagaries of organizational life cycles and economic trends can be an effective vehicle for systematic experiments in cooperative thinking. Although specific needs and interests have prompted higher education and industry to collaborate more closely, the cumulative effect of these alliances is more than the sum of specific agreements. Partnerships allow both communities to address common, long-range problems, develop new perspectives and approaches, and gain an awareness of each other's organizational culture. The great promise that partnerships hold lies in these less tangible endeavors. Likewise, the future of partnerships is brightest in those areas that extend beyond the immediate domain of a college and a corporation. By pooling the resources, wisdom, and ingenuity of both communities, alliances can be of substantial benefit to all of us as we ponder the role and impact of technology on our lives. They can help us understand current and future changes and allow us to prepare ourselves for them. In short, greater collaboration between higher education and industry permits us all to become more active partners in our society.

Delays, however, have dangerous ends. Safeguarding the future of partnerships requires that we manage them well today. This future is ours not to inherit but to create. We can accomplish this by developing a strategic vision of the technological, knowledge-intensive world we are entering, by ensuring that our institutions are adequate to this world, and by fostering the partnerships that will shape and secure our future.

Appendix

1983 National Assembly Advisors and Speakers

1983 National Assembly Advisors

George Baughman
Director of Special Projects
Ohio State University

Lewis Branscomb
Vice President and Chief Scientist
IBM

Edward E. David, Jr.
President
Exxon Research and Engineering Company

Rogers Finch
Executive Vice President
Illuminating Engineering Society

Pat Hill Hubbard
Vice President for Education
American Electronics Association

Roland Rautenstraus
Professor of Civil Engineering
Former Dean, School of Engineering
and former President University of Colorado

Juan A. Rodriguez
Vice President for Research and Technology
Storage Technology Corporation

Rhett Speer
Consultant on Science and Technology
National Conference of State Legislatures

Richard Van Horn
Provost
Carnegie-Mellon University

John Wirt
Senior Associate
National Institute of Education

Roy S. Yamahiro
Vice President of Organization Development and Training
Federal Express

1983 National Assembly Speakers

James Alleman
District Staff Manager
Mountain Bell

George Baughman
Director, Office of Special Projects
Ohio State University

James Botkin
Technology & Strategy Group

A. Paul Bradley
Vice President
American Management Association

Christine Bullen
Assistant Director
Center for Information Systems Research
Massachusetts Institute of Technology

Stuart Bundy
President
Henry Ford Community College

Nolen M. Ellison
President and Chief Executive Officer
Cuyahoga Community College District

Rogers Finch
Executive Vice President
Illuminating Engineering Society

Donald R. Fowler
General Counsel
California Institute of Technology

Roy V. Gavert
Executive Vice President
Public Systems Group
Westinghouse Electric Corporation

Harold Hodgkinson
Senior Fellow
Institute of Educational Leadership

Ted Hollander
Chancellor of Higher Education,
New Jersey

Pat Hill Hubbard
Vice President for Education
American Electronics Association

Richard D. Lamm
Governor
State of Colorado

Ben Lawrence
President
NCHEMS

Nanette Levinson
Director
Institute on Industry-University
Research Relations
The American University

Jana B. Matthews
Director of Management Services
NCHEMS

Theodore Mulford
Vice President, Link Flight
Simulation Division
Singer Company

Ray Orbach
Provost
College of Letters & Science
University of California at Los Angeles

Don Phillips
Special Science Advisor
North Carolina Board of
Science & Technology

Roland Rautenstraus
Professor of Civil Engineering
Former Dean, School of Engineering and
former President, University of Colorado

Louis Robinson
Director of University Relations
IBM

Robert Rosenzweig
President
Association of American Universities

David Saxon
President
University of California

John B. Slaughter
Chancellor
University of Maryland
(former Director, NSF)

Howard Sorrows
Director of Technological Assessment
National Bureau of Standards

Monte C. Throdahl
Senior Vice President
Monsanto Company

Elizabeth Useem
Associate Professor
University of Massachusetts—
Harbor Campus

Richard Van Horn
Provost
Carnegie-Mellon University

Gordon Voss
Minnesota State Legislator

Elisabeth Zinser
Senior Academic Officer
School of Medicine
University of North Dakota

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NOTE: Unreferenced citations in the text were made by speakers at the 1983 NCHEMS National Assembly, held in Denver, Colorado, in February 1983. Their remarks are derived from unedited transcriptions not available to the public.

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lanaging the Partnership Between Higher Education and Industry

y Jana B. Matthews and Rolf Norgaard

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